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STUDY TO DEVELOP AN IMPROVED UNIVERSAL POSITION SWITCH FOR LAUNCH COMPLEX 39 SERVICE ARM APPLICATION

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16. Abstract

This study includes a determination of desired universal position switch characteristics, a survey of the state of the art, selection of test candidates, design verification testing and evaluation, and refurbishment of test samples to incorporate certain design changes found to be desirable during testing.

The study revealed a lack of off-the-shelf switches which have characteristics approaching those determined to be desirable for this application. Three switch designs were selected for design verification testing. Two switches were new designs; the third switch involved minor design changes and repackaging.

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FINAL REPORT

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FOR

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ABSTRACT

This report presents the results of a study to develop an improved universal position indicator switch for use on Kennedy Space Center (KSC) Launch Complex 39 (LC-39) service arms. The study was performed by Chrysler Corporation Space Division (CCSD) for the National Aeronautics and Space Administration (NASA) under contract NAS 10-6063.

The scope of the study included a determination of desired universal position switch characteristics, a survey of the state-of-art, selection of test candidates, design verification testing and evaluation, and refurbishment of test samples to incorporate certain design changes found to be desireable during testing.

The study revealed a lack of off-the-shelf switches which have characteristics approaching those determined to be desireable for this application. Three switch designs were selected for design verification testing. Two switches were new designs and the third switch involved minor design changes and repackaging.

Two of the three switch designs, after incorporation of design changes to correct deficiencies in contact rating (60 Hz) and vibration capabilities, respectively, are suitable candidates for qualification testing and use on LC 39. The third switch design requires repackaging into a smaller volume in order to receive further consideration. These switch designs offer many improved operational characteristics over existing switches, together with a substantial cost reduction potential. The improved characteristics include an increased ability to withstand side loads, increased pre-travel and overtravel, reduced differential travel, and increased repeatability.

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Section 1

SUMMATION

1.1 OBJECT

The object of this report is to summarize the activities of CCSD during a 17-month study to develop an improved universal position switch for use on KSC LC-39 service arms. This study was performed by CCSD for NASA-KSC under contract NAS10-6063. The effort was divided into two main Tasks. Task I - Analysis activities included establishment of requirements for a universal switch, determining the state-of-art, and selection of test candidates. Task II - Testing activities included design, procurement, fabrication, testing and evaluation of test samples, and incorporation of design changes determined to be desireable during testing.

1.2 CONCLUSIONS

1.2.1 Task I - Analysis

The efforts of CCSD during Task I have already been documented in CCSD Technical Report TE-EE-68-37, "Task I Report, Study to Develop an Improved Universal Position Switch for Launch Complex 39 Service Arm Application". The conclusions of Task I are briefly summarized in the following paragraphs.

1.2.1.1 Characteristics of Universal Switch

The characteristics for an improved universal position switch intended for service arm applications where retrofit of existing switches is not a main concern were determined and are tabulated in table A-1, Appendix A.

1.2.1.2 State-of-Art Survey

The survey of the state-of-the-art for position switches indicated that there were no "off-the-shelf" switches being manufactured which could meet or exceed the universal position switch characteristics. A tabulation of the manufacturers contacted during this survey and the significant features of each manufacturer's design is presented in table A-2, Appendix A.

1.2.1.3 Test Candidate Selection

Three candidate switches as indicated in Table 1-1 were selected for inclusion in the Task II - Testing effort.

Table 1-1 Summary of Selected Test Candidates

CCSD Part No.	Type of Switch	Mfg.	Reasons for Selection	Development Status
SKEE-159	Mechanical	CCSD	1. Improved Functional Characteristics 2. Low cost 3. Interchangeable with present switches	New Design
SKEE-160	Hybrid Mechanical /Electro-optic	CCSD	1. Improved Functional Characteristics 2. Low Cost 3. Mechanically inter-changeable with present switches	New Design
SKEE-161	Proximity	Electro-Sonic Control	1. Hermetically-sealed moving parts 2. No contact between switch and prime mover	Repackaging, circuitry modification

Figures B-1 and B-2, Appendix B, show assembly drawings and operational requirements of the CCSD built switches. Figure B-3 shows an outline drawing and operational requirements for the proximity switch, SKEE-161.

1.2.2 Task II Testing

1.2.2.1 Mechanical Switch, SKEE -159

The mechanical switch provided improved functional-operational characteristics. Testing verified that the actuator mechanism design was satisfactory. However, failure of the internal switching units to meet the contact rating, coupled with the unavailability of satisfactory direct replacement switches, necessitated a significant redesign of the internal switch configuration.

Redesigned mechanical switch, SKEE-159B, has the required contact rating, is capable of providing the same improved operating characteristics and utilizes the same actuator mechanism as the SKEE-159 switch. The limited functional testing of the refurbished switch confirmed that this redesigned switch will perform satisfactorily.

1.2.2.2 Electro-optical Switch, SKEE-160

The electro-optical switch provided improved functional-operational and electrical characteristics. Testing verified that the actuator mechanism design, and the electrical circuit design was satisfactory; however, failure of a relay during vibration and the marginal vibration capability of the electronic support bracket, necessitated redesign of these affected components.

Redesigned switch SKEE-160B has much greater vibration resistance, and an 18-36 vdc input voltage capability. In addition, it is capable of providing the same improved functional-operational and electrical characteristics, and utilizes the same actuator design as the SKEE-160 switch.

Limited functional testing of a switch refurbished to include the needed design changes confirmed that the redesigned switch will perform satisfactorily.

1.2.2.3 Proximity Switch SKEE-161

Testing confirmed that the proximity switch is generally capable of meeting all requirements. However, there is a need for improved packaging, manufacturing and quality control techniques.

1.3 RECOMMENDATIONS

1.3.1 Universal Position Switch Characteristics

It is recommended that the universal position switch characteristics as determined during Task I should be revised to include the revised, better defined requirements, listed in table 1-2.

Table 1-2, Revisions to Universal Switch Characteristics

Type Characteristic	Item	Universal Switch Requirement
Design and Construction	Actuation	Direct actuated switch; mobile ball-plunger; maximum angle of approach-30 degrees
	Terminations	Connector to mate with MS3106-14-6S
	Contact Arrangement	Passive Switch: DPDT Active Switch: SPDT
Functional-Electrical Performance	Input Power	Passive Switch: Zero Active Switch: 18 to 36 VDC
Functional-Operational Performance	Differential Travel	Direct actuated switch: 0.025 inch maximum (mechanical) Direct actuated switch: 0.010 inch maximum (electro-optical) Proximity switch: less than 1/10 of sensing distance
Environmental Performance	High Temp.	+160° F stabilized

1.3.2 Mechanical Switch, SKEE-159B

It is recommended that the redesigned mechanical switch be considered for qualification testing for application as a replacement for present switches. This switch offers improved mechanical characteristics, is completely interchangeable with the presently used switches, and offers a significant cost reduction potential.

1.3.3 Electro-optical Switch, SKEE-160B

It is recommended that the redesigned electro-optical switch be considered for qualification testing for uses in future applications where an extremely accurate, repeatable position detection is needed or in present or future applications where a prime consideration is the capability to replace a switch without necessitating recalibration of the entire system.

1.3.4 Proximity Switch, SKEE-161

Although this switch offers the greatest potential for meeting all universal switch requirements, it cannot be directly applied to the majority of applications. For this reason, it is not recommended that any qualification testing be performed. However, for future design of swing arms, it is recommended that consideration be given to qualifying a repackaged (size reduction) switch built under more stringent quality control surveillance.

Section 2

DISCUSSION

2.1 INTRODUCTION

Problems have been experienced for various reasons with position indicator switches used on KSC service arms at LC-39. Some of the problems were a result of the severe environments encountered at KSC, such as the exposure to salt spray, temperature cycling, humidity, etc. Other problems arose because of infrequent operation of equipment. The main problems, however, appear to be caused by difficulty in adjusting switches, and by other generally poor mechanical characteristics.

For this reason, a Request for Quotation (RFQ) for a study contract to develop an improved universal position switch was issued in May 1968. A synopsis of the previously reported Task I - Analysis activities, and the complete CCSD activities during Task II - Testing are discussed in the following pages.

2.2 TASK I - ANALYSIS

2.2.1 Determination of Requirements for Universal Position Switch

2.2.1.1 Background Information

The requirements for the improved universal position switch were determined by review, analysis, and evaluation of all available documentation on the present switches and installations, and by firsthand inspection of actual installations. A survey of the present service arm switch applications indicated that in the majority of applications, the switches were utilized to provide indications only. They were not required to provide extremely precise indications of position, but rather to give indications of position extremes such as: door closed, gate raised, arm retracted, etc. In a number of applications it was evident that difficulties were encountered in properly adjusting the switch and ensuring that the overtravel capabilities were not exceeded.

A breakdown of the various types of motions to be detected confirmed the need for a universal type actuation as indicated in table 2-1.

Table 2-1 Position Switch Applications

Type of Motion to be Detected	No. of Applications
Axial	53
Lateral	47
Rotary	40

2.2.1.2 Universal Switch Characteristics

Table A-1 in Appendix A, presents the characteristics for an improved universal position switch. The table also includes the existing requirements for switches used on the service arms and the requirements that the existing switches meet.

Under Design and Construction, two very significant new characteristics were specified. One was the capability of a switch being replaced by another switch of the same type without requiring system recalibration. This requires that all switches of a given design have a very accurate, repeatable operate point. The other was that the switch be capable of actuation from any direction, eliminating the need for keying. Both capabilities would greatly facilitate installation and application of switches. Under Functional-Electrical performance, the only new characteristic which was specified was an input power requirement. A 22 to 32 VDC range was determined to be acceptable. (Later, in Task II, this was revised to 18 to 36 VDC.)

Under Functional-Operational performance, a number of significant changes were made. For direct-actuated switches, a nominal pre-travel of 0.25 inch was specified which represented a significant increase over the 0.05 inch nominal pre-travel of present switches. This would permit an installation to be designed so that the actuator could remain in contact with the cam to minimize impact, side loading, and reduce the possibility of bounce. Similarly a nominal 0.5 inch overtravel requirement was specified. This represents a significant increase over the 0.12 inch nominal travel of present switches. With the increased overtravel, the problems of properly installing and adjusting switches are greatly alleviated.

Another significant change was the definition of side-load capability. A capability of operating with force applied at an angle of 40° degrees from the normal was specified. This is extremely important since in the majority of cam type applications the switch is subjected to a side load.

Under Environmental-Performance, the only change was to specify the vibration test as a non-operational test since the indications are not required at the time of engine ignition when the severe vibration levels are encountered.

2.2.2 Determination of the State-of-the-Art

Over 40 switch manufacturers were contacted in attempting to determine the state-of-the art for position switches. A tabulation of the manufacturers is presented in table A-2, appendix A. In some cases where a switch appeared promising, but required some additional developmental effort to meet the requirements for this application, it appeared that the lack of visibility of a future market deterred the manufacturer from making any redesign effort.

The Rolamite concept was investigated without success for possible adaptation to an improved position switch.

2.2.3 Selection of Candidates for Task II - Testing

2.2.3.1 Trade-off analysis

After determining the improved universal switch characteristics and conducting a state-of-the-art survey, it was apparent that there were no "off-the-shelf" switches that possessed the desired characteristics. Thus it was necessary to perform a trade-off analysis to select the concepts which offered the greatest possibility of attaining the objectives of the study. From a list of nine promising concepts, three were selected. They included a mechanical switch with improved operating characteristics which was completely interchangeable with present switches. A second candidate was a hybrid-mechanical/electro-optical switch. This switch offered all the improved performance capabilities of the mechanical switch, and in addition because of a unique utilization of an electro-optic position sensor, the switch could easily be built so that one electro-optic switch could replace another, without requiring recalibration/operation of the system. This switch concept however was only partially electrically interchangeable with the existing switches since it required 28 VDC power. The third candidate was a proximity switch. Although not electrically or mechanically interchangeable with present switches, it could meet all universal switch characteristics and simplify installation design.

2.2.3.2 Description of Candidates

Figures B-1, B-2 and B-3, Appendix B, list the operational requirements and show assembly/outline drawings and parts lists for the three candidates. Paragraph 2.3.1 contains a detailed description of each switch.

2.3 TASK II - TESTING

2.3.1 Switch Design, Fabrication and Assembly

2.3.1.1 Mechanical Switch, SKEE 159

A. Switch Design. The preliminary design concept established in Task I was fully detailed during the initial months of Task II. Figure B-1 shows the final assembly drawing for the switch. A complete set of documentation (engineering sketch-type drawings) was furnished under separate cover to the NASA Technical Supervisor. Figure B-4 shows the completed switch assembly. A primary goal of the switch design was to develop a low cost switch, capable of meeting a majority of the universal position switch characteristics. To accomplish these goals the following design constraints were imposed:

1) Standard off-the-shelf hardware should be utilized to the greatest extent feasible.

2) Pre-travel and over-travel should nominally be 0.25 inch and 0.50 inch respectively.

3) The actuator must be capable of withstanding side-loads.

4) The switch must be mechanically and electrically interchangeable with existing LC-39 switches.

5) Stainless steel hardware should be utilized to the greatest extent feasible.

A dual spring actuating mechanism concept consisting of actuator-plunger, bearings, yoke, springs, guide rods, and associated hardware was utilized. This design was favored over a single spring mechanism because it facilitated the use of standard springs, was easier to adjust, and required less intricate machining.

A 3/8 inch diameter actuator-plunger (Find Number 5 of figure B-1) was utilized. This large diameter together with the use of a $1\frac{1}{4}$ inch length of axial sleeve bearings (F/N 2 and 3) provide an adequate side load capability. The bearings are sintered bronze impregnated with Teflon-Lead powder. The bearings are manufactured by Garlock. A simple formed yoke (F/N 13), which is riveted to the actuator-plunger, is utilized to compress the springs. Guide rods (F/N 17) which are threaded into the base (F/N 1), serve to key the actuator to the base, locate the springs, and provide a mounting for the stop plate. Two simple retainers (F/N 27) are used; one retains the bearing, while the other is utilized in adjusting the springs. A cylindrical rubber bumper (F/N 29) which is installed on the actuator-plunger shaft acts as a shock absorber in the event that the actuator-plunger is suddenly released after being fully depressed.

A Viton O-ring (F/N 4) mounted ahead of the bearing serves to seal the interior of the switch. Viton was selected because it has indefinite life and does not require age control. A Teflon wiper (F/N 6) which is located ahead of the O-ring serves to scrape any corrosion, dirt, etc. off the actuator shaft. Teflon was selected because it has a low coefficient of friction, and will not be affected by the KSC environments.

The actuator-plunger utilizes the conventional roller wheel (F/N 8). Although this does not meet the universal switch requirements, it was utilized because it was not possible to develop a more universal actuator such as a ball-type during this program.

A single-pole, hermetically-sealed Microswitch (F/N 12) manufactured by The Microswitch Division of Honeywell appeared to meet all functional and environmental requirements, could be obtained with a single actuator for ganging switches, and was selected for the application. A roller wheel type actuator for the Microswitches was selected to minimize friction between this actuator and the actuator-plunger. A bracket of welded construction (F/N 7) was designed to support the switches and provide adjustment capability. After final adjustment, dowel pins were utilized to maintain the position of the bracket relative to the base. After final Microswitch adjustment, epoxy was utilized to maintain the position of the switches.

Wiring from the Microswitch was routed via grommets in the stop plate to the hermetic-sealed type connector (F/N 26). All solder connections at the connector and the Microswitch were potted to provide strain relief and moisture resistance.

The envelope diameter was determined by the physical characteristics of the Microswitches. A nominal 2 inch diameter standard stainless steel container was modified and utilized for the cover (F/N 25). At final assembly, after all adjustments were made, the cover was welded to the base.

B. Fabrication - During the course of the fabrication, several substitutions were necessary. They included the following:

1) Bumper (F/N 29). The bumper design was revised to utilize a three layer construction because the cost of a sheet of material of the desired thickness was prohibitive.

2) Wiper (F/N 6) - Nylon was substituted for Teflon because Teflon of the proper diameter could not be obtained in the allotted time.

3) Springs (F/N 10) - Cadmium-plated steel springs were utilized in place of stainless steel, because off-the-shelf stainless springs could not be located in time.

C. Assembly - During assembly, several minor modifications had to be made. These included the addition of a grommet to the stop plate (F/N 30) to facilitate wire routing. It was noted during assembly that the method of adjusting and securing the adjustment of the Microswitches was slightly more involved than desireable due to the number of parts involved.

2.3.1.2 Mechanical/Electro-optical Switch, SKEE-160

A. Switch Design. Similarly as for switch SKEE-159, the preliminary design concept established in Task I was fully detailed during the initial months of Task II. Figure B-2 shows the assembly drawing, parts list, and operational requirements for this switch. A complete set of documentation (engineering sketch-type drawings) was submitted under separate cover to the NASA Technical supervisor. Figure B-4 shows the completed switch assembly. The design goals and constraints for this design were identical to that of switch SKEE 159 except that the switch would only be partially electrically interchangeable with existing switches. The major difference in the switches was that an electronic module utilizing a light emitting diode and light sensitive transistor and a relay replaced the microswitches, and the switch end of the actuator-plunger was machined to create a vane to block the optical path. Because of the similar designs, this section will be limited to a discussion of the electronic design and packaging.

The electronic assembly, (printed-circuit (pc) cards and brackets), are shown on drawing SKEE 167. The bracket (F/N 1) of welded construction was designed to provide a mounting for the pc cards and accurately locate the optic elements relative to the base of the switch and the plunger. The electronic components exclusive of one dropping resistor were located on two similarly shaped printed circuit cards. The resistor was mounted on the stop plate on insulated stand-off terminals.

After alignment/adjustment of the optical elements, the printed circuit cards were conformal coated with polyurethane to ruggedize the construction. Dowel pins were utilized to maintain the position of the bracket relative to the base.

A general purpose crystal can size relay was mounted on a special bracket (F/N 7) of welded construction. The bracket was attached to the base of the switch. Because of space limitations, and possible interference with the rivets on the plunger-yoke combination, it was necessary to locate the relay a considerable distance above the base of the switch. In order to satisfy the required AC contact rating, it was necessary to insulate the relay case from the structure of the switch.

The interconnecting wiring between the relay, dropping resistor, and pc cards was routed through grommets on the stop plate. At final assembly all slack in wiring below the stop plate was eliminated so that it was impossible for any wiring to be contacted by the moving actuator-plunger. Solder connections at connector and pc board were potted for strain relief. Plastic sleeving was utilized at the relay solder terminations.

The electronic circuit is shown in schematic form on SKEE 169. The basic circuit has been designed and tested for application on S-IB stage prevalves and is documented in CCSD technical bulletin, TB-EE-67-48. Changes that were needed to adapt the circuit to this application are summarized below:

Table 2-2 Required Electro-optical Circuitry Changes

Item	Former Capability	Required Capability for This Application	Remarks
Input Voltage	24-32VDC	18 to 30 VDC	Regulator circuit redesign
Ambient temperature	-65°F to 165°F	5 to 190°F*	Increase Power Rating of several components, modify values.
Contact Rating	2 amp resistive 28 VDC	3 amp resistive, 115V, 60 Hz	Utilize new relay, insulate relay from switch structure.
* Later reduced to 160°F			

The redesigned circuit was breadboarded to confirm that the circuitry would function as designed, prior to fabrication of the pc cards.

B. Fabrication - The substitutions were the same as those needed during fabrication of SKEE 159, and discussed in 2.3.1.1.B.

C. Assembly. The desired spacing between optical elements of 0.055 $\pm$ .005 inch coupled with the actuator-plunger vane thickness of 0.031 complicated the assembly process. The vane thickness was altered to approximately

0.020 inch. An optical element spacing of 0.100 inch minimum is desireable.

2.3.1.3 Proximity Switch, SKEE-161

The proximity switch, manufactured by Electro-Sonic Control required some modifications to an existing switch design. These modifications consisted of circuit changes to provide operation at a lower ambient temperature, and at different input voltages, utilization of a hermetically-sealed relay, and repackaging.

A. Switch Design. Figure B-3 appendix B, shows the outline dimensions of the switch, the wiring diagram, and the operational requirements. Since this switch was not designed by CCSD, no additional documentation was supplied. Figure B-5 shows the completed switch assembly. During the initial three months of Task II, the vendor completed his redesign/repackaging effort.

B. Fabrication/Assembly. The vendor was unable to build the switch using a completely enclosed welded enclosure as was desired for the KSC environment. The problem was encountered because a metallic plate over the sensing face of the device greatly reduced the sensing sensitivity. Various metals were tried without success. Extremely thin plates had less effect on sensitivity, however welding problems prevented this approach. Finally, it was agreed that one side of the switch (containing the sensing face) could be non-metallic. Epoxy was utilized on this face, and had no effect on sensitivity.

Low temperature compensation was another problem area and ultimately each device was individually compensated using component values selected during testing.

The vendor was unable to procure the desired stainless steel, hermetic-sealed connectors due to a schedule problem, and CCSD authorized the hot tin-dipped connector which does not have the desired corrosion resistance.

2.3.2 Design Verification Testing

2.3.2.1 General

The design verification test program consisted of both functional and environmental tests. The purpose of the tests was to verify that the candidate switches can meet the design requirements.

A detailed test procedure, CCSD test procedure TP-RE-69-219 entitled "Procedure for Design Verification Tests for Improved Universal Position Switch for Launch Complex 39 Service Arm Application" defined the procedures, to be followed during testing. The procedure was submitted to NASA-KSC for approval prior to intiation of testing.

The test sequence and specimen assignments were as follows in table 2-3.

Table 2-3. Sequence of Tests and Specimen Assignment

Test	SKEE 159 Serial No.		SKEE 160 Serial No.		SKEE 161 Serial No.	
	101	102	201	202	1	2
Visual Inspec.	X	X	X	X	X	X
Initial Functional	X	X	X	X	X	X
Input Voltage Variation			X			X
Low Temperature			X			X
High Temperature			X			X
Vibration	X	X	X	X	X	X
Humidity-Temp. Cycling	X			X	X	X
Salt Fog	X	X	X		X	
Life Cycling	X	X	X	X	X	X

2.3.2.2 Test Results

A. General - CCSD technical report TR-RE-69-240 entitled "Design Verification Test Report for Study to Develop an Improved Universal Position Switch for Launch Complex 39 Service Arm Applicator", documents the complete test program, and contains all test data. A brief summary of the test results for each switch, is presented in the following paragraphs. This report was submitted under separate cover.

B. SKEE 159 - Test Results. During initial functional tests the switches exceeded all requirements except for S/N 102 which did not meet the 4 lb restoration force requirement (probably caused by excessive wiper friction). During vibration, both samples failed and were inoperative after test. Disassembly, and failure analysis indicated that the Microswitches had shifted relative to the mounting bracket. Vibration testing with cover removed, revealed movement of the microswitches relative to the actuator-plunger at critical frequencies. Corrective actions consisted of increasing the step on the actuator-plunger from 0.020 inch to 0.030 inch to accommodate the relative motion, and etching the stainless steel bracket to obtain better adhesion with epoxy. Vibration testing was then satisfactorily completed on rebuilt switches without any sign of contact chatter.

After the 10-day humidity temperature cycle test of switch S/N 101, it did not meet insulation resistance requirements and the roller wheel on the plunger was badly corroded. Investigation revealed that an improper size O-ring had been installed on the switch, and that a stainless steel roller wheel had not been purchased. After correcting these errors, the test was repeated on Switch S/N 102, and it met all requirements.

After the salt fog test, the actuator-plunger of switch S/N 102 had a tendency to stick in the depressed condition, and the switch failed to meet the restoration force requirement. It is felt that this tendency to stick was a result of the substitution of Nylon in place of Teflon for

the wiper. The Nylon is hygroscopic and tends to swell after absorbing moisture; and does not have the lubricating properties of Teflon.

During life test, after only 1600 cycles of controlling a 3 ampere, 115 volt 60 Hz load, the contacts of one Microswitch of S/N 101 welded and became inoperative. The contacts of the other Microswitch failed in a similar manner after a total of only 2200 cycles. When the manufacturer of the switch was contacted regarding the failures, it was learned that the switch has a rating of 3 amperes at 28 VDC and 115 Volt/400 Hz, but is not recommended for use on 60 Hz applications. Microswitch does not manufacture a switch in that size and configuration which has a 60 Hz switching capability. This switch was operated mechanically for the 50,000 cycles, in spite of the electrical contact failure, to determine the mechanical life of the switch on this sample with the operate force applied at an angle of 30° from the normal. The mechanical performance was satisfactory. The other switch (S/N 102) completed 30,400 cycles of life test before an internal Microswitch became erratic. This Microswitch was controlling a 3 ampere-28 VDC resistive load. Disassembly after test revealed no evidence of excessive wear, or fatigue on either switch. The bearings appeared in excellent condition.

C. SKEE-160 Test Results - Both samples met all requirements at initial functional test except for pre-travel. Due to an improper initial adjustment (failure to allow for increased thickness of a substitute laminated bumper), both switches had less than the 0.20 inch minimum pre-travel.

The switch met all requirements during input voltage variation test. During vibration, S/N 202 was subjected to some abnormal conditions when the helicoil insert on the test fixture into which the switch was threaded, became loose. Shortly afterward the switch became inoperative. After disassembly, inspection revealed a brcken interconnecting wire on a pc card, and cracked welds on the electronic support bracket. This sample was then removed from further vibration testing, because the bracket could not be repaired without rebuilding the entire electronic module.

The other switch successfully completed sinusoidal and random vibration testing in two axes, but failed during random vibration testing in the final axis. After disassembly, inspection revealed that a relay contact terminal had fractured at the relay header. Additionally it was noted that a coil lead, inside the relay, had broken near the location where it is welded. It was felt that the failure was caused because the relay had been subjected to excessive vibration levels during the test because of bracket resonance.

Similarly as was experienced on the mechanical switch, an incorrect size O-ring had been installed on the electro-optical switches, and switch S/N 202 was not functional after the 10-day humidity-temperature cycling test. Disassembly revealed that a high resistance path had formed as a result of electrolytic corrosion of dissimilar metals. After installing the proper size O-ring, this 10-day test was repeated on switch S/N 201, and it met all requirements.

Both samples performed satisfactorily in life testing. One contact of the relay in switch S/N 201, which controlled a 3 ampere, 120 volt, 60 Hz load began operating intermittently after 47,300 cycles (requirement is for 10,000 cycles of operation). Similarly as for the mechanical switch, one of the switches was subjected to a 30° side load during the test.

There was no evidence of any unusual wear or fatigue after test. The bearings appeared in excellent condition.

D. SKEE-161 Test Results. During the initial functional testing, one of the two proximity switches (S/N 1) had generally unpredictable characteristics. Surrounding metallic objects had a significant effect on its sensitivity. The other switch (S/N 2) performed satisfactorily.

During input voltage variation testing (18-36 VDC) switch (S/N 2) marginally failed to meet the repeatability requirements at the voltage extremes. However the reported shift in operate point 0.018 inch maximum approached the accuracy of the test set-up.

At low temperature, a significant shift in operate point of 0.080 inch was observed for S/N 2. This fails to meet the repeatability requirement of 0.007 inch maximum deviation. At the high temperature extreme, the switch met all requirements.

During vibration testing, several of the mounting flanges on switch S/N 2 fractured. This was not unexpected considering the mass of the specimen. Mounting straps were improvised to secure the switch for the remaining vibration tests. With the exception of the broken flanges, the switches satisfactorily completed vibration testing.

At about this time in the test program it was discovered that switch S/N 1 could be made to perform in a fairly predictable and stable manner by placing a ferrous $\frac{1}{4}$ inch diameter bolt across the bottom of the sensing face. This technique was utilized in remaing tests.

Humidity temperature cycling tests were performed on both sample of SKEE-161. Initially this had not been planned, when it was believed that the switch would be constructed with a completely welded enclosure. This test was added to the procedure when it became necessary to permit a non-metallic face. S/N 1 satisfactorily completed the 10-day humidity-temperature cycling test, but S/N 2 had low insulation resistance and operated very unstablely immediately after the test. Later when "dried-out" the switch performed satisfactorily. Subsequent investigation revealed a small break in the case flange. Moisture apparently entered the switch at this break and caused the erratic operation.

During life test, both samples operated 50,000 cycles with only a minor degradation of insulation resistance noted in the sample S/N 1. This reduction of insulation resistance was attributed to the relay which was controlling a 3 ampere, 115 volt, 60 Hz load.

2.3.2.3 Analysis of Test Results

A summary of the test results on all switches is presented in table A-3 appendix A.

Aside from problems encountered because of materials substitutions both intentional and accidental, and minor adjustment problems which are typical of first-run production item, the major problems uncovered during testing are summarized in table 2-4.

Table 2-4. Design Deficiencies Determined by Testing

Switch Type	Problem Area
SKEE 159	1. The switch does not have the required 115 volt/60 Hz contact rating
SKEE 160	1. The relay mounting method has inadequate vibration capability. 2. The electronic support bracket has marginal vibration capability.
SKEE 161	1. Erratic behavior of one of two samples. 2. Fracture of mounting flange in vibration 3. Moisture penetration in humidity-temperature cycle test. 4. Failure to meet repeatability requirements.

In spite of the overall generally satisfactory performance of the mechanical switch, the inability to meet the 60 Hz contact rating necessitates replacement with another switching unit. The testing, however, did confirm that the actuating mechanism is capable of providing the improved mechanical characteristics, such as side-load capability and increased pre-travel and overtravel.

Similarly the electro-optic switch generally met all requirements except for vibration test. A better method of mounting the relay to minimize the likelihood of failures as a result of vibration is needed. The testing did confirm the extremely repeatable performance of an electro-optical switching device, and did verify the circuit changes made to adapt the circuitry to this application. Also, similar to the mechanical switch, the testing confirmed the design of the actuating mechanism and the ability to provide improved mechanical characteristics.

The proximity switch performance was generally quite satisfactory. Aside from the obvious need for heavier flanges, it appears that the other testing anomalies could be corrected or eliminated by improved manufacturing and quality control techniques.

2.3.3 Definition of Modifications to Correct Design Deficiencies

In view of the inability of any of the test candidates to meet all design requirements, action was initiated by CCSD to define the modifications

required to enable the switches to meet the design requirement. It was then agreed that these modifications should be incorporated to the extent feasible in one sample each of switches SKEE 159 and SKEE 160. The change (contract modification No. 2) was to be accomplished by refurbishment of existing test samples.

2.3.2.1 SKEE 159 Modifications

The failure of the Microswitches to meet the 60 Hz contact rating necessitated replacement of the switching units. It was determined that a miniature, hermetically sealed switching unit, part number 10AT17-01, manufactured by the Klixon Controls Division of Texas Instruments Incorporated had the required contact ratings. Additionally, the switch had a much higher vibration resistance (65g). After a detailed examination of the switch operating and physical characteristics, a method of adapting this switch to the existing SKEE 159 configuration was developed which would supply the desired improved operating characteristics. Figure B-6 shows an assembly drawing and parts list for this redesigned switch. It has been identified as SKEE 159B. Complete documentation was supplied to the NASA Technical Supervisor under separate cover.

The switch actuating mechanism is identical to the SKEE 159 except for the modification to the actuator-plunger. Actuation of the switching units is accomplished when the actuator-plunger is depressed sufficiently to cause the ball (F/N 24) to exert force on the actuator of the switching unit. The actuator-plunger is designed to provide clearance between the ball and switching unit during the pre-travel length of the actuator-plunger. A self-aligning bearing (F/N 33) is located immediately below the switch mounting block (F/N 7) to maintain the relative position of the actuator-plunger and the switching units. A self-aligning bearing was selected to simplify the installation/adjustment of the switch assembly.

The basic switching units have external threads. After the proper adjustments have been made, the switches are secured with a jam nut and loc-tite.

A switch mounting block is attached to the plate (F/N 11) which is attached to the guide rods by jam nuts.

2.3.3.2 SKEE 160 Modifications

In modifying the optical switch to provide increased vibration resistance, the approach selected consisted of attaching the various support brackets to a stiffened stop plate. With the electronic bracket and relay support bracket attached to the stop plate in addition to the guide rods, a mutually stabilizing effect under vibration would be obtained.

Since the switch modifications were rather extensive it was feasible to modify the electrical circuitry to meet the desired 18 to 36 VDC input voltage capability. (CCSD had not been informed of this requirement until after the electronic circuits board for the SKEE 160 switches had already been designed and ordered. Consequently the capability of the SKEE 160 Switch was for an input voltage range of 18 to 30V.)

Figure B-7 shows an assembly drawing and parts list for this redesigned switch. It has been identified as SKEE 160B. Complete documentation was supplied to the NASA Technical Supervisor under separate cover.

The switch actuating mechanism is identical to the SKEE 160 switch. The electronic support bracket is a sturdy sheet metal bracket. After the printed circuit cards are attached to the bracket and adjusted, dowel pins are utilized to secure the position of the bracket relative to the base and stop plate respectively. After installation on the bracket, the pc card assembly is completely potted with the exception of the optical elements.

The relay is mounted inverted on spacers. A longer spacer extends to the stop plate. Standard screw insulators are utilized to insulate the relay flange from the structure of the switch. Potting is utilized at the base of the switch to provide positive lateral restraint for the top of the relay. The relay header is potted to provide strain relief and moisture protection for the wires connected to the relay. A schematic diagram of the redesigned electrical circuitry is shown in figure B-10.

2.3.3.3 SKEE 161 Modifications

A reduction in the volume of these switches would greatly enhance its utility. A package size of 2 x 2 x 3 inches was discussed with the vendor, and they have said it would be feasible.

2.3.4 Fabrication and Testing of Redesigned Switches

2.3.4.1 Redesigned Mechanical Switch

The modifications described in paragraph 2.3.3.1 were incorporated to the extent feasible in switch S/N 102. Because of the limited amount of time available for the incorporation of modifications, and the need to limit expenses, it was not possible to include all desired improvements. Figure B-8, Appendix B, presents an assembly drawing and parts list for the refurbished switch. It has been designated SKEE 159A. Complete documentation for this switch was furnished under separate cover to the NASA technical supervisor.

The deviations from the desired redesigned configuration (SKEE 159B) include the following:

A. Wiper - Nylon wiper was utilized in place of Teflon.

B. Springs - Cadmium-plated were utilized in place of stainless steel.

C. Roller wheel - 3/8 inch diameter in place of a 1/2 inch dia.

D. Switch mounting block - width had to be altered.

E. Stop plate - Constructed of two thinner stop plates riveted together.

F. An aluminum support plate was utilized on the self-aligning bearing in place of stainless steel.

At final assembly, it was discovered that a stainless steel electrical termination on one of the Klixon switches had not been tin-plated, and it was not possible to make a proper solder connection. Ultimately, a repair was attempted which consisted of fastening a terminal, to which a wire could be soldered, to the termination on the Klixon switch. During repair the termination on the Klixon switch loosened slightly but remained functional. During the subsequent potting operation, additional handling of the terminal aggravated the condition. After potting the switch would not function properly.

Except for this problem due to the wrong terminal finish, the assembly and adjustment was much simpler for the redesigned switch. During testing prior to soldering, the switches met the operational requirement for pre-travel, differential travel, overtravel, and simultaneity.

2.3.4.2 Redesigned Electro-optical Switch

The modifications described in paragraph 2.3.3.2 were incorporated to the extent feasible in switch S/N 201. As for the mechanical switch SKEE 159A, it was not possible to incorporate all desired improvements. Figure B-9, Appendix B, presents an assembly drawing and parts list for the refurbished switch which has been designated as SKEE 160A. Complete documentation for the refurbished switch was furnished under separate cover to the NASA technical supervisor.

Deviations from the desired redesigned configuration (SKEE 160B) include the wiper, spring, and roller wheel deviations that were also present on the refurbished mechanical switch, and the following:

a. Stop plate - The tabs on the new stop plate were bent in the wrong direction. (manufacturing error)

b. The top spacer which secures the relay should have a #4-40 thread in place of #6-32 at the relay flange.

c. Soldering of components to pc cards by non-production personnel necessitated larger potted module.

The assembly of this switch was simpler than the previous version, since the optical spacing had been increased to 0.1 inch.

After assembly, exclusive of welding the cover to the base, the refurbished switch was tested to verify proper operation. The switch operated satisfactorily and met all requirements including operation with 18-36 VDC input voltage variations.

APPENDIX A

TABULAR DATA

Table A-1. Summary of Switch Characteristics

CHARACTERISTICS					REMARKS
TYPE	ITEM	EXISTING SYSTEM REQUIREMENTS FOR SERVICE ARM SWITCHES	REQUIREMENTS OF UNIVERSAL SWITCH	REQUIREMENTS OF EXISTING SWITCHES	
DESIGN AND CONSTRUCTION	MAINTAINABILITY AND CALIBRATION	Not specified	Free from maintenance	Require maintenance or replacement	Improvement
	INTERCHANGEABILITY *WITHOUT CALIBRATION	Not specified	Interchangeability without calibration	Interchange requires calibration	Improvement
	MOUNTING	3/4 inch through-hole in mounting plate with key-way.	Direct actuated switch: 3/4 in. through-hole in mounting plate without key-way.	3/4 in. through hole in mounting plate	Improvement
			Proximity switch: 3/4 in through-hole in mounting plate; or surface mount.		Improvement
	DIMENSIONS	Overall length of 7 inches maximum	Direct actuated switch: overall length 7 in. max. Proximity switch: overall length 5 in. max.	Overall length: 6.32 in. maximum	Dimension of 75M18669 which is largest.
	MATERIAL	Resistance to corrosion	Direct actuated switch: Exposed case metal-SST 304 series	Exposed metal of SST 300 or 400 series	Improvement may be obtained by elimination of all highly dissimilar metals within Grade B,C, D seal environments, or exposed areas.
			Proximity switch: case-SST 304 series; sensing face (to be determined)	Not applicable	
	SEALING	Grades A,B,C,D applied in accord with KSC-STD-131 Para. 5.3.2	Direct actuated switch: Basic switch-Grade A Actuator - Grade A,B,C.	Grades A,B,C	No change, improvement is desirable.
	ACTUATION	Provide actuation from linear/rotational motions; maximum angular range of approach is 30 degrees from normal.	Direct actuated switch: mobile ball-plunger; Maximum angle of approach - 40 degrees.	Roller plunger; normal actuation only is specified	Improvement
			Proximity switch: proximity of ferrous metal target; Maximum angle of approach: - 90 degrees	Not applicable	Improvement
	TERMINATIONS	Connector, integrally mounted (KSC-STD-131)	Passive switch: to mate with MS3106-14-6S Active switch: to mate with MS3106-20-7S	Connector to mate with MS 3106-14-7S and MS3106-14-6S	No change
	PHYSICAL CONFIGURATION	One piece (sensor/control/switch/connector)	One piece	One piece	No change
	CONTACT ARRANGEMENT	Single pole double throw (SPDT) for majority and double pole double throw (DPDT)	DPDT	SPDT, and DPDT	Improvement
FUNCTIONAL-ELECTRICAL PERFORMANCE	INPUT POWER	No requirement	Passive switch: zero Active switch: 22 to 32 V.DC.	No requirement	System cabling is 6 wire which may be used on SPDT applications
	CONTACT RATING	Majority of applications - 0.1 Amp. inductive at 28 V.DC.	1.5 Amp. inductive, 3 amp. resistive at 28 V.DC. and 115 V.AC.	3 Amp. resistive only at 28 V.DC. 10 Amp. resistive only at 28 V.DC.	
	VOLTAGE DROP OF CONTACTS	Less than 0.5 V.DC. (KSC-STD-131)	Less than 0.5 V.DC.	Not specified	
	SIMULTANEITY	Not specified	Passive switch: 0.03 maximum deviation	0.03 inches maximum deviation	No change
			Active switch: not applicable	Not applicable	Improvement
	LIFE	10,000 cycles (KSC-STD-131)	10,000 cycles at rated current	10000 cycles	No change
	INSULATION RESISTANCE	20 megohms minimum at 500 V.DC.	20 megohms minimum at 500 V.DC.	20 megohms minimum at 500 V.DC.	No change
	DIELECTRIC STRENGTH	Not specified	Less than 1 milliampere leakage at 1000 V.RMS (Mil-S-8805B)	Not specified	

*Ability to replace one switch with another of the same type.

Table A-1. Summary of Switch Characteristics (continued)

TYPE	ITEM		EXISTING SYSTEM REQUIREMENTS FOR SERVICE ARM SWITCHES	CHARACTERISTICS REQUIREMENTS OF UNIVERSAL SWITCH	CHARACTERISTICS REQUIREMENTS OF EXISTING SWITCHES	REMARKS
FUNCTIONAL-OPERATIONAL PERFORMANCE	SENSITIVITY	PRETRAVEL	Not specified	Direct actuated switch: 0.20 to 0.30 inch	0.030 to 0.09 inch	Improvement
		SENSING DISTANCE CAPABILITY	Not specified	Proximity switch: at least 0.75 inch but not greater than 1.25 inch	Not applicable	Improvement
	DIFFERENTIAL TRAVEL		Not specified	Direct actuated switch: 0.010 inch maximum (mechanical)	0.005 to 0.05 inch	Improvement
				Direct actuated switch: 0.010 inch maximum (Electro-optical)	Not applicable	Improvement
				Proximity switch: lesss than 1/10 of sensing distance	Not applicable	Improvement
	OVERTRAVEL		Not specified	Direct actuated switch: 0.45 to 0.55 inch	0.125 to 0.200 minimum	Improvement
				Proximity switch: unlimited, laterally; 0.75 in. maximum, axially.	Not applicable	Improvement
	OPERATING FORCES	ACTUATION, AXIAL	Not specified	Direct actuated switch: 6 lb. weight min.	6 lb. Weight minimum	No change
				Proximity switch: no force required	Not applicable	Improvement
		FULL OVERTRAVEL, AXIAL	Not specified	Direct actuate switch: 30 lb. weight max.	30 lb. weight maximum	No change
				Proximity switch: no force exists	Not applicable	Improvement
		FULL OVERTRAVEL, NON-AXIAL, APPROACH. (40 deg. from normal)	Not specified	Direct actuated switch: 40 lb. weight max.	Not specified	Improvement - Defines Side load capability
				Proximity switch: no force exists.	Not applicable	Improvement
		RESTORATION, AXIAL	Not specified	Direct actuated switch: 4 lb. minimum	4 lb minimum	No change
				Proximity switch: no force required	Not applicable	Improvement
	STOP FORCE (additional to operate force)		Not specified	Direct actuated switch: 35 lb. weight	Not specified	Improvement
				Proximity switch: 35 lb. weight	Not applicable	Improvement
	REPEATABILITY		Not specified	Passive Switch: 0.040 inch max. deviat. Active Switch: 0.005 inch max. deviat.	Not specified	Improvement
	RESPONSE TIME		Not specified	30 millisecond maximum	Not specified	
ENVIRONMENTAL PERFORMANCE	LOW TEMPERATURE		+5 Deg. F. for 2 hours (KSC-164)	Equal or greater than system requirements.	Equal or greater than system requirement.	No change
	HIGH TEMPERATURE		+160 Deg. F. for 72 hours +190 Deg. F. stabilized (KSC-164)	Equal or greater than system requirement.	Equal or greater than system requirement.	No change
	VIBRATION (non-operational)	(SINUSOID)	10 to 40 Hz at 0.25 in. D.A. 40 to 2000 Hz at 21 G (KSC-164)	Equal or greater than system requirement. Equal or greater than system requirement.	Equal or greater than system requirement.	Status of requirement at this date: tests are operational.
		(RANDOM)	0.225 G^2/Hz (KSC-164)	Equal or greater than system requirement.	Equal or greater than system requirement.	
	HUMIDITY		72 Deg. F. to 160 Deg. F. at 95 per cent humidity. (KSC-164)	Equal or greater than system requirement.	Equal or greater than system requirement.	No change
	SAND AND DUST		4 hours at 77 Deg. F. 2 hours at 160 Deg. F. 100 to 500 cu. ft/min (KSC-164)	Equal or greater than system requirement.	Equal or greater than system requirement.	No change
	SALT FOG		5 percent for 240 hours at 95 Deg. F. (KSC-164)	Equal or greater than system requirement.	Equal or greater than system requirement.	No change
	EXPLOSION		32 plus or minus 5 per cent by volume of hydrogen. Pressure 13±1 to 15±1 PSI. (KSC-164)	Equal or greater than system requirement.	Equal or greater than system requirement.	No change

TABLE A-2. SURVEY OF CANDIDATE SWITCHES

COMPANY		SIGNIFICANT FEATURES							ADVANTAGES	DISADVANTAGES	REMARKS
NAME	ADDRESS	P/N or MDL/N	ACTUATION	SEALING	ELECTRICAL: INPUT POWER	ELECTRICAL: CONTACTS	ELECTRICAL: RATING	OPERATION			
General Equipment and Mfg. Co.	3300 Fern Valley Road Louisville, Ky. 40213	MDL 43-500 A/D	Proximity of ferrous material and magnetic operation.	Grade A (Hermetic) Basic 3W	Zero	Independent make and break 2 circuits.	0.8A - DC 10A - AC	Repeatability: .002 in. Response time: 0.008 sec. Temperature range: -50 to +250 Deg. F. Sensing: Adjustable $\frac{1}{4}$ to $\frac{1}{2}$ inch Differential travel: 2 times sensing distance. Maximum over travel force (on case mounting).	Economical. No power. Long life. Fast response No mechanical actuation.	Large differential travel contacts and rating	Requires modification to incorporate: SST case, integral connector, DPDT contacts, increase in contact rating, increase in sensing distance, decrease in differential travel. Requires vibration study. This candidate is considered promising.
Kinetics Corp	410 S.Cedros Ave., Solana Beach, California	1117	Mechanical		Zero	DPDT	10A - DC 28 VDC	Repeatability: Temperature: -65 to 275 Deg. F. #1117 - Pretravel 0.06 in.; differential travel 0.05 in. Over travel: 0.18 in., 35 lb. Minimum required speed 3 in/sec. #1172 - Pretravel: 0.065 in. Over travel: 1.185 in. 35 lb. Other characteristics: Same as #1117	No power. Fast response	Costly. Minimum actuation speed. Operate characteristics not suitable.	Requires change to operating characteristics. Because of high cost of No. 1117-1 which is presently used, together with our study constraints of time and cost, the availability of other avenues of approach, this candidate is not considered promising.
General Electric Co. General Purpose Control Department	Bloomington, Illinois	CR 115 A.AS	Proximity vane or magnet.	Oil tight.	Zero	(1) Break or (1) Make	6A AC 24 to 240 VAC	Repeatability: 0.0025 Temperature: -4 to 167 Deg. F. Sensing: 3/8 to 5/8 in. Response: 1 millisecond			Large differential travel is inherent in this design type. This candidate is not considered promising.
Controls Corp Control Switch Division	1420 Delmar Drive Folcroft, Pa. 19032	Various	Mechanical. Plunger, rotary leaf.	Resilient Seal Silicon rubber diaphram.	Zero	Various	10A	Temperature: -65 to +250 Deg. F.	Economical. No power.		Requires change to operating characteristics and construction. This candidate is considered promising.
Dolan-Jenner Industries, Inc.	200 Ingalls Court, Melrose, Mass. 02176	Various	Proximity. Fiber optic interruption.		Power required 2.5 W	SPST	3A	Temperature: 10 to 120 Deg. F Response: 25 Ms Maximum range: Opposed: 2 in.; Reflected: 3/8 in.		Installation is complex. Costly.	Optic arrangements exposed to prevailing light ambient conditions are not suitable. No enclosed optics are developed. This candidate is not considered promising.
Adams & Westlake	1025 N. Michigan St. Elkhart, Ind. 46514	Various HF Series	Proximity. Magnet operation.		Power to coil.	Two circuit	5A	Temperature: Not determined Response: 4.5 Ms Sensing: Not determined Differential travel:		Operation limited to ± 30° of vertical.	Because of the mounting constraint, this candidate is not considered promising.
Micro Switch Division of Honeywell	Freeport, Ill. 61032		Proximity. Variable reactance sensor. Ferro and non-ferro targets. Alternate sensor - Reed type		Power to amplifier relay.	One circuit and use relay.	Relay	Repeatability: Not determined Temperature: -20 to 190 Deg. F. Sensing: (nominal) 1/2 in. and 3/4 in. and 2 in. Life: One billion cycles.	Sensor installation is versatile.	System is complex. Costly.	Requires modification to minaturized one piece design. No affirmative response was made to query on development. This candidate is not considered promising.
Tann Controls Co.	20210 Sherwood, Detroit Mich. 48234	M.R. & T Series	Proximity. Ferrous or magnet operated.	Sealed	Zero	SPDT	0.5A DC	Repeatability: Not determined Temperature: Not determined Sensing: On 0.009 in. Off 0.160 in.	No.mech.oner. Economical. No power. Long life. Fast response	Rating too low Requires relay	No response was received after a follow-up telephone inquiry. This candidate is not considered promising.
Electro-Development Corp.	Box 100 16700-13 West Lynnwood, Wash. 98036	MDL 899 Syst.	Proximity. Variable reactance sensor. Ferro and non-ferro targets.	Sealed	Power to amplifier relay.	Determined by relay.	Determined by relay.	Repeatability: Not determined Temperature: -40 to 149 Deg. F Sensing: 0.275 to 0.325 in dead band 0.005 to 0.030 Differential travel: 0.005 to 0.030 in. Power to switch less than 4 W	Versatility of sensor installation. High environmental capability.	System is complex. Costly.	Characteristics of design are fairly compatible. Further study is recommended for a one piece design including relay and connector with increase of sensing distance. This candidate is considered promising.
Automatic Equipment Co.	1653 Central Parkway, Cincinnati, Ohio.	MDL 105 106	Proximity. Variable reactance sensor.	Sealed	Power to amplifier relay.	SPDT	1A DC Resist. 15A DC inrush	Repeatability: Not determined Temperature: Not determined Sensing: $\frac{1}{2}$ to 5/8 in. Differential 3/8 to 1/32 in. Deadband: 1/8 to 1/16 in. Power input: 15 to 25 W	Versatility of sensor.	System is complex.	Requires modifications to incorporate: SST case, connector, DPDT contacts, and circuit change for 28 VDC. This candidate is not considered promising.
Cutler-Hammer Inc.	4201 N. 27 St Milwaukee, Wis. 53216	Type PL	Proximity. Variable reactance sensor.		Power to amplifier relay.	1 N.O. 1 N.C.	16A DC	Sensing: 0.1 to 0.4 in.	Versatility of sensor.	System is complex.	Requires modification to incorporate: SST case, connector, output relay, circuit change to 28 V. DC. and one piece design. This candidate is not considered promising.
Electro Product Laboratories, Inc.	Chicago, Ill.	4910-AN	Proximity. Variable reactance sensor.		Power to amplifier relay.	Determined by relay.	Determined by relay.	Repeatability: Not determined Sensing: 1/2 in.			Requires modification to incorporate: SST case, circuit change to 28 VDC input, and one piece design. No development planned. This candidate is not considered promising.
Texas Instruments Inc.- Metal & Controls Div.	34 Forest St. Attleboro, Mass.	AT 1-1 Series	Mechanical. Klixon Snap Action element.	Enclosure hermetic	Zero	Multipole	3A DC Resistive	Repeatability: Not determined Temperature: -65 to 275 Deg. F. Forces: Actuate 20 oz. Release 1 oz. Max. 5 lb. Displacement: Pretravel 0.006; Differential travel 0.003 Overtravel 0.003 in. Contact Separation: 0.010 in.; Minimum cycles 15,000	Small: basic switch hermetically sealed. Shock and vibration resistant.	Small travel.	Requires modification to incorporate: increased travel characteristics, new design presently in test by NASA. This candidate is not considered promising.

Table A-2. Survey of Candidate Switches (continued)

COMPANY		SIGNIFICANT FEATURES									
					ELECTRICAL						
NAME	ADDRESS	P/N or MDL/N	ACTUATION	SEALING (hermetic)	INPUT PWR	CONTACTS	RATING	OPERATION	ADVANTAGES	DISADVANTAGES	REMARKS
ELECTRONIC CONTROL CORP.	DETROIT, MICH.	PS 721	Proximity - variable reactance bridge sensing	Unsealed Amplifier/ Control	115 VAC 0.5 A or less	NO., & N.C.	5A, 115 VAC Resist	Sensing distance: 1 in. or less, to 24 in., depending on sensor; max. operate rate: 600 per minute;ambient temperature: 0 to 115 deg. F	Large sensing range	Requires redesign of packaging	Requires modification to incorporate: SST case, internal connector, DPDT contacts, circuit change to 28 V.DC., one piece design. Manufacturer not willing to participate in further development
COTO-COIL CO. INC.	PROVIDENCE, R.I.		Proximity - electro magnetic coil - reed switch					Various voltages: 6112, 24, 32, 48 V. DC.		Low rating, poor characteristics	Long differential travel is inherent in this design. Redesign of output circuit required. Candidate is not promising.
BENTLY NEVADA CORP.	MINDEN, NEVADA	3000	Proximity - variable reactance sensing & eddy current principle	Unsealed Amplifier/ Control	18 VDC	Unknown	Unknown	Unknown		Requires redesign of packaging	Extensive modification and development would be required. This candidate is not considered promising.
WESTINGHOUSE ELECTRIC CORP. GENERAL CONTROL DIV.	BUFFALO, N.Y.	6520390/ 300 C Series	Proximity - variable reactance sensing	Unsealed Amplifier/ Control	117 VAC 4 W	Unknown	0.33 A. D.C. Inductive at 24 VDC	Sensing distance: 1/8 in. to 2" maximum Operations per second 5 to 20 Response time: 25 milliseconds Differential Distance: 1/5 of sensing distance.	Large sensing range	Requires redesign of packaging	Requires extensive modification: for 28 V.DC. Integral connector, minature circuitry, output relay, one piece design. This candidate is not considered promising.
ALCO ELECTRONIC PRODUCTS INC.	LAWRENCE, MASS.	RS-24PR	Proximity - magnetically operated reed switch	Plastic package	None	N.O.	0.5 A	Sensing distance: 0.8 in. between magnet center and sensor face center.		Low current rating; contacts; long differential	Existing design: characteristics are inadequate. Satisfactory modifications are not easily realized using reed switch. This candidate is not considered promising.
SQUARE D CO. INDUSTRIAL CONTROL DIV.	MILWAUKEE, WISC.	Class 9007 Type VQ-1	Proximity - variable reactance bridge sensing	Unsealed	28 VDC if modified 8 V.A.	N.O.	0.3 A. D.C.	Sensing distance: 3/4 in. Differential distance: 1/16 inch Ambient temperature: - 10°C to 60°C			Design uses a reed switch. It has high differential travel. Requires extensive modification and development. This candidate is not considered promising.
THE ARROW-HART & HEGEMAN ELECTRIC CO.	HARTFORD, CONNECTICUT		Proximity - variable reactance bridge sensing					This switch is independently under development, on long-term low priority basis.			Manufacturer although interested, decided not to respond to invitation to bid.
THE NATIONAL ACME CO.	CLEVELAND, OHIO	EA9700 Series	Proximity - variable reactance bridge sensing	Unsealed	125 VAC 3 VA 1 W	DPDT	10 A Resist. 250 V AC	Sensing range: 0.56 in.		Two piece unit	Requires modification to incorporate: SST case, integral connector, one piece design. This candidate is now considered promising.
R.B. DENISON INC.	BEDFORD, OHIO	LC2-LB2	Mechanical	Enviromental Seal, NEMA	Zero	IND - Inc	0.6A 115 V DC	Pretravel 0.7 in; Differential travel: .02 in.; Total travel: .22 in.; operate force: 32 oz.		Non-hermetic seal, wrong characteristic contact form.	Complete new design and development is required. This candidate is not considered promising.
HAYDON SWITCH & INSTRUMENT INC.	WATERBURY, CONN.	No.6272	Mechanical	Basic switch is hermetic sealed	Zero	DPDT	3A.DC. Inductive 28 VDC	Pretravel: unknown but small; differential travel: .016 in.; Overtravel: .015 in.; operate force 4402; release force: 10 oz; actuation: leaf roller	Hermetic	Operate characteristics not suitable; prefer plunger roller	Modification is required to a basically good switch to obtain suitable operate characteristics. This candidate is considered promising.
ALLEN-BRADLEY CO.	MILWAUKEE, WISCONSIN	Various	Mechanical	Environmental Seal, NEMA	Zero	INC. IND.	0.4A.DC 125 VDC	Pretravel: .08 in.; differential travel; .04 in.; total travel: .25 in; operate force 3.5 lb.		Non-hermetic seal;large	Requires extensive modification to incorporate: SST case, integral connector, one piece design, minaturization. Candidate is not promising.
CHERRY PRECISION SWITCHES	HIGHLAND PARK ILL.	Various	Mechanical	Unsealed	Zero	DPDT	20A., 125 V AC	Typical: .100 in; differential travel: .015 in.; overtravel: .050 in.; operate force: 45 oz.		Non-hermetic seal; characteristics not suitable; plastic material	Requires modification to operate characteristics and case construction. This candidate is not considered promising.
FARMER ELECTRIC PRODUCTS CO. INC.	NATICK, MASS.	PS3/PA 3	Proximity - high freq. variable reactance sensing	Environmental Seal	Unknown	1 N.O. - to operate plug in relay	According to relay selection	Sensing: 1 in distance, target: 3 sq.in.;	Sensing distance is adequate	Non-hermetic seal; require minaturization.	Requires extensive modification to incorporate SST case, integral connector, minaturization, one piece design. Manufacturer declined to respond.
AMTRON, INC.	MIDLOTHIAN, ILL.	11382	Proximity - reed switch, magnetic operated	Unknown	Zero	1 N.C.	0.25 A	Sensing: 3/8 in. distance, target: magnet Mdl 11382		Non-hermetic seal;characteristics unsuitable.	Large differential travel is inherent to this design. Also extensive modifications are required to circuitry and packaging. Candidate is not considered promising.
VAP-AIR DIV. VAPOR CORP.	6444 W Howard St. Chicago, Ill. 60648		Proximity; Variable reactance sensor		Power to amplifier relay 2.5W	N.O. or N.C.	0.5 A.DC	Sensing: 0.30 in.	High environmental capability	System is complex	Requires modification to incorporate SST case, integral connector, minaturization, one piece design. Manufacturer declined to respond. This candidate is not considered promising.

Table A-2. Survey of Candidate Switches (continued)

COMPANY		SIGNIFICANT FEATURES									
					ELECTRICAL						
NAME	ADDRESS	P/N or MDL/N	ACTUATION	SEALING	INPUT POWER	CONTACTS	RATING	OPERATION	ADVANTAGES	DISADVANTAGES	REMARKS
Fifth Dimension, Inc.	P.O.Box 483 Princeton, N.J.		Magnetically actuated	To be determined		SPST by relay		Not determined		Contact configuration	Requires modification. Manufacturer did not respond. No further action recommended.
GENCO	Clawson, Michigan	Various	Mechanical actuated	Environmental	Zero	Various	Various	Various styles		Too large	Requires redesign to meet requirements. Manufacturer is not interested in development. No further action is recommended.
Automation Devices Inc. Peeco Div.	Fairview, Penn.	Not known	Mechanical actuated	Not determined	Zero	Various	Various	Not determined			Manufacturer has no suitable item and is unwilling to respond further.
The Gems Co Inc.	Farmington, Connecticut	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Various	Not determined			Manufacturer states that their product is not suitable for our application. No further action is necessary.
Electronics Corp.	Cambridge, Mass.	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they are not interested in responding to this study.
Robotron Corp.	Detroit, Mich.	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they have no suitable product.
Robertshaw Controls Co.	Columbus, Ohio	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they have no suitable product.
De-Tec-Tronic Corp.	Chicago, Ill.	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they have no suitable product.
Raymond Engineering Inc.	Middletown Conn.	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they have no suitable product.
Controlotron Corp.	Farmingdale, N.Y.	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they have no suitable product.
Aladdin Controls Div.	Nashville, Tenn.	Not known	Magnetically actuated	Not determined	Unknown	Unknown	Unknown	Not determined			Manufacturer states that they have no suitable product.
Electro-Sonic Control	Monteca, Calif.	1469	Variation of reactance in oscillating field by nearby metallic target	Hermetic	Unknown	DPDT	1.5A Inductive at 28 V.DC	Sensing distance: 1 inch. Differential travel: less than 0.05	Meets all requirements		Requires modification to circuit and packaging. Further study is recommended.

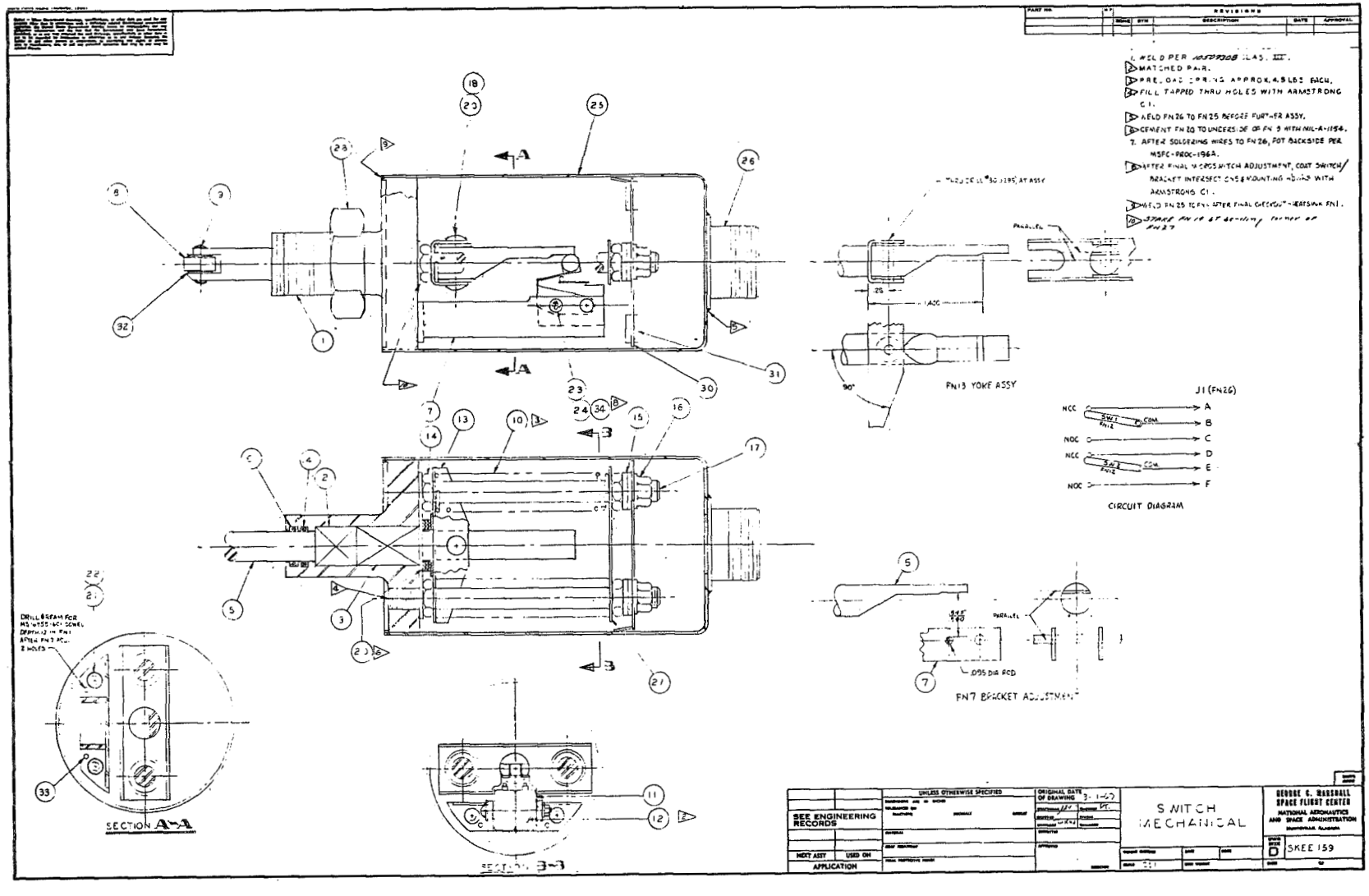
TABLE A-3 SUMMARY OF TEST RESULTS

CHARACTERISTICS				PERFORMANCE DURING TEST		
TYPE	ITEM		REQUIREMENT	SKEE-159 (MECHANICAL)	SKEE-160 (ELECTRO-OPTIC)	SKEE-161 (PROXIMITY)
FUNCTIONAL-ELECTRICAL	INPUT POWER		PASSIVE - NONE ELECTRO-OPTIC- 18-30 VDC PROXIMITY - 18-36 VDC	NOT APPLICABLE	MET ALL REQUIREMENTS	REPEATABILITY & DIFFERENTIAL TRAVEL REQUIREMENTS WERE NOT MET AT INPUT VOLTAGE EXTREMES
	CONTACT RATING/LIFE		10,000 CYCLES - 3 AMP RESISTIVE AT 28 VDC & 115V/60HZ	AFTER 1600 CYCLES IN LIFE TEST WITH AC LOAD CONTACTS WELDED	GREATLY EXCEEDED REQUIREMENTS (OPERATED 47,000 CYCLES)	GREATLY EXCEEDED REQUIREMENTS (OPERATED 50,000 CYCLES)
	SIMULTANEITY		PASSIVE SWITCH - 0.030 INCH	GREATLY EXCEEDED REQUIREMENTS	NOT APPLICABLE	NOT APPLICABLE
	INSULATION RESISTANCE		20 MEGOHM MIN.	MET ALL REQUIREMENTS	MET ALL REQUIREMENTS	SEE HUMIDITY TEMP. CYCLING TESTS - OTHERWISE MET REQUIREMENTS
FUNCTIONAL-OPERATIONAL	SENSITIVITY	PRE-TRAVEL	DIRECT ACTUATED SW. 0.20 TO 0.30 INCH	MET REQUIREMENTS	DUE TO IMPROPER INITIAL ADJUSTMENT SWITCH DID NOT MEET REQUIREMENTS BY 0.02 INCH	NOT APPLICABLE
		SENSING DISTANCE	PROXIMITY SW. - 0.75 TO 1.25 INCH	NOT APPLICABLE	NOT APPLICABLE	ONE OF TWO SAMPLES ON INITIAL TEST, HAD UNPREDICTABLE SENSING CHARACTERISTICS.
	DIFFERENTIAL TRAVEL		DIRECT ACTUATED SW.- 0.010 INCH MAX. PROXIMITY SW. -0.015 INCH MAX	TYPICAL VALUES RANGE FROM 0.020 to 0.030 INCH	GREATLY EXCEEDED REQUIREMENTS	MET REQUIREMENTS EXCEPT DURING INPUT VOLTAGE TEST AT MAX INPUT VOLTAGE
	OVER TRAVEL		DIRECT ACTUATED SW.- 0.45 TO 0.55 INCH	DUE TO IMPROPER INITIAL ADJUSTMENT, SWITCH DID NOT MEET REQUIREMENT BY 10%	MET REQUIREMENTS	NOT APPLICABLE
	OPERATING FORCES	INITIAL DISPLACEMENT	6 LB WITHIN 0.015 INCH OF "FREE" POSITION *	MET REQUIREMENTS	MET REQUIREMENTS	NOT APPLICABLE
		OPERATE FORCE	6 to 25 LB.	MET REQUIREMENTS	MET REQUIREMENTS	NOT APPLICABLE
		FULL OVERTRAVEL	25 LB. MAX.	BECAUSE OF THE SUBSTITUTION OF NYLON FOR TEFLON IN CONSTRUCTION OF THE WIPER, THE SWITCH DID NOT MEET REQUIREMENTS.	MET REQUIREMENTS	NOT APPLICABLE
		RESTORATION FORCE	4 LB. MIN. WITHIN 0.015 INCH OF "FREE" POSITION *	BECAUSE OF THE SUBSTITUTION OF NYLON FOR TEFLON IN CONSTRUCTION OF THE WIPER, THE SWITCH DID NOT MEET REQUIREMENTS.	BECAUSE OF THE SUBSTITUTION OF NYLON FOR TEFLON IN CONSTRUCTION OF THE WIPER, THE SWITCH DID NOT MEET REQUIREMENTS.	NOT APPLICABLE
	REPEATABILITY		PASSIVE SW. - 0.04 IN MAX. ELECTRO-OPTIC SW. - 0.005" MAX PROXIMITY SW.- 0.007 IN. MAX.	MET REQUIREMENTS	TEST SET-UP WAS NOT CAPABLE OF DETERMINING SWITCH CAPABILITY.	DID NOT MEET REQUNT. ON OPERATE POINT - MAX. VARIATION OF 0.082 INCH WAS MEASURED (LOW TEMP.)
ENVIRONMENTAL	LOW TEMP.		-5°F	NOT TESTED	MET REQUIREMENTS	UNSATISFACTORY - OPERATE POINT SHIFTED 0.08 INCH
	HIGH TEMP.		160°F	NOT TESTED	MET REQUIREMENTS	SATISFACTORY
	VIBRATION (NON-OPERATIONAL)		SINUSOIDAL - 25g PEAK RANDOM - 0.225 g^2/cps	MET REQUIREMENTS - NO CONTACT CHATTER DETECTED	DUE TO COMPONENT FAILURES TESTING NOT SUCCESSFULLY COMPLETED.	MOUNTING FLANGES FRACTURED OTHERWISE MET REQUIREMENTS
	HUMIDITY - TEMP CYCLING		90°F TO 160°F 95% R.H. - 10 DAYS	MET REQUIREMENTS	MET REQUIREMENTS	ONE SWITCH NON-OPERATIONAL AFTER TEST - AND LOW INSULATION RESISTANCE
	SALT FOG		5%, 95°F, 10 DAY	MET REQUIREMENTS	MET REQUIREMENTS	CORROSION ON CASE

* The maximum displacements at which this force is applicable was defined at the conclusion of testing.

APPENDIX B

ILLUSTRATIONS



B-1

Figure B-1. Mechanical Switch, SKEE 159 (Sheet 1 of 5)

DESIGN AND OPERATING REQUIREMENTS

1. Termination: hermetically sealed SST shell to mate with MS3106R14S-6S.

2. Sealing: Basic switch is hermetically sealed. Actuator assembly is sealed per KSC-STD-131 para. 5.3.2.

3. Mounting: Plate through-hole with keying.

4. Contact Arrangement: DPDT

5. Material of Case and Connector: weldable corrosion resistant steel.

6. Actuator Approach (angular range): 0 to 30 degrees.

7. Contact Rating: 1.5 amperes inductive and 3 amperes resistive at 28 V DC and at 115 V AC.

8. Simultaneity: Deviation less than 0.030 in.

9. Pretravel: 0.20 to 0.30 inch

10. Differential Travel: 0.010 inch maximum

11. Overtravel: 0.45 to 0.55 inch.

12. Axial Operating Forces: 6 lbs. weight minimum at beginning of travel 25 lbs. weight maximum of total travel.

13. Response Time: 30 milliseconds maximum

14. Repeatability: 0.040 in. maximum deviation

15. Low Temperature: 5 F for 2 hours (KSC-STD-164)

16. High Temperature: 160°F for 72 hours

17. Vibration (Non-operational): Sinusoidal: -10 to 44 Hz at 0.25 in. DA
    44 to 2000 Hz at 25 g peak
    Random: -0.225 G2/Hz (KSC-STD-164)

18. Humidity: 72°F to 160°F at 95 percent humidity

19. Sand and Dust: 4 hours at 77°F
    2 hours at 160°F
    100 to 500 cu ft/min (KSC-STD-164)

20. Salt Fog: 5 percent for 240 hours at 95°F (KSC-STD-164)

21. Explosion: 32 plus or minus 5 percent by volume of hydrogen
    Pressure: 13.1 to 15.1 psi (KSC-STD-164)

22. Life: 10000 actuations (KSC-STD-131)

Figure B-1. Mechanical Switch, SKEE 159 (Sheet 2 of 5)

PARTS LIST

SIZE ASSY DWG D | PL SKEE159

1 FINDING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Base		D	SKEE147-3		1		
2	Bearing - SLEEVE				06DU08	1		Garlock Bearing Prod.
3	Bearing - SLEEVE				06DU12	1		Garlock Bearing Prod.
4	"O" Ring			MC 266 12 FA		1		
5	Plunger		B	SKEE145		1		
6	Wiper		B	SKEE152-1		1		
7	Bracket		B	SKEE146		1		
8	Bearing - Ball				77-R-2	1		New Departure or Equiv.
9	Roll Pin				79-028-125-0375	1		ESNA Corp.
10	Spring- Compression				22	2		California Spring Co.
11	Actuator				JS-31	1		Micro Switch
12	Switch			MS27216-1		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
			FN31 QTY WAS 2		

ORIG DATE 3-6-69
DFMN JCM CHK PT
TYP ENG
SUBMITTED
APPROVED

LIST OF PARTS FOR
Switch
Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG D | PL, SKEE 159 | Sheet 1 of 3

Figure B-1. Mechanical Switch, SKEE 159 (Sheet 3 of 5)

PARTS LIST

SIZE ASSY DWG: PL SKEE-159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
13	Yoke		B	SKEE 1.9		1		
14	Nut - Plain Jam			MS-35691-7		4		
15	Washer - Flat			AN960 C416		4		
16	Nut - Self-Locking			MS-21043-4		2		
17	Rod - Threaded		B	SKEE 3&4 -		2		
18	Rivet			MS-20613 4012		1		
~~19~~	~~Nut - Self-Locking~~			~~MS-21043-04~~		~~1~~		
20	Washer - Flat			AN-960-04		2		
21	Screw			MS-16995-9		2		
22	Lockwasher			MS-35333-135		2		
23	Screw - Pan hd.			MS-51957-9		2		
24	Nut - Self-Locking			MS-21042-02		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		

ORIG DATE 3-6-69

CFMN [illegible] CHK [illegible]

TYP ENG

SUBMITTED

APPROVED

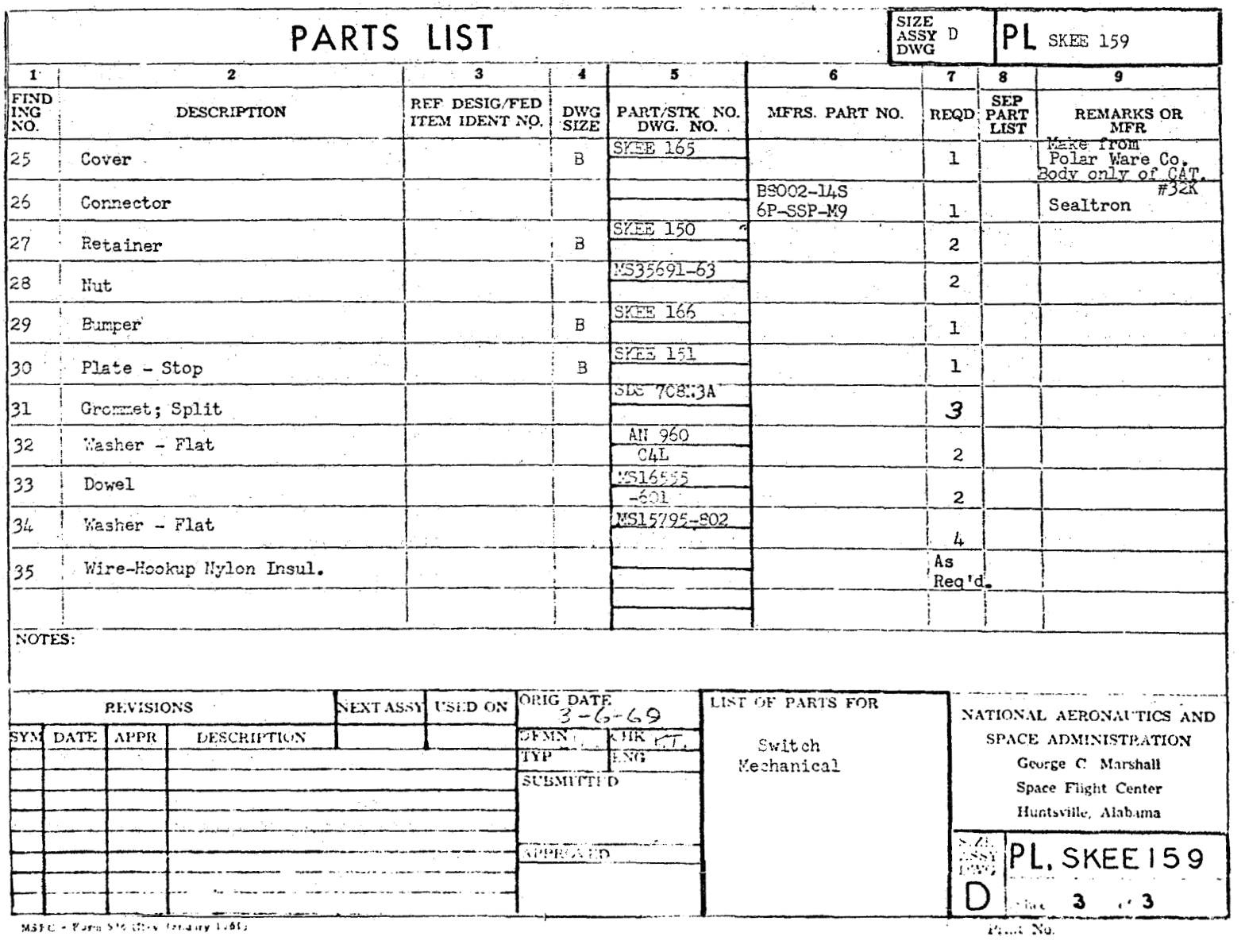
LIST OF PARTS FOR: Switch Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: D — PL. SKEE 159

Sheet 2 of 3

Figure B-1. Mechanical Switch, SKEE 159 (Sheet 4 of 5)



PARTS LIST

SIZE ASSY DWG: D | PL SKEE 159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
25	Cover		B	SKEE 165		1		Make from Polar Ware Co. Body only of CAT. #32K
26	Connector				BS002-14S 6P-SSP-M9	1		Sealtron
27	Retainer		B	SKEE 150		2		
28	Nut			MS35691-63		2		
29	Bumper		B	SKEE 166		1		
30	Plate - Stop		B	SKEE 151		1		
31	Grommet; Split			SDE 708-3A		3		
32	Washer - Flat			AN 960 C4L		2		
33	Dowel			MS16555 -601		2		
34	Washer - Flat			MS15795-802		4		
35	Wire-Hookup Nylon Insul.					As Req'd.		

NOTES:

REVISIONS SYM	DATE	APPR	DESCRIPTION	NEXT ASSY	USED ON

ORIG DATE 3-6-69

DFMN | CHK | ENG | TYP

SUBMITTED

APPROVED

LIST OF PARTS FOR: Switch Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: D | PL, SKEE 159

Sheet 3 of 3

MSFC - Form 516 (Rev. January 1961)

Sheet No.

Figure B-1. Mechanical Switch, SKEE 159 (Sheet 5 of 5)

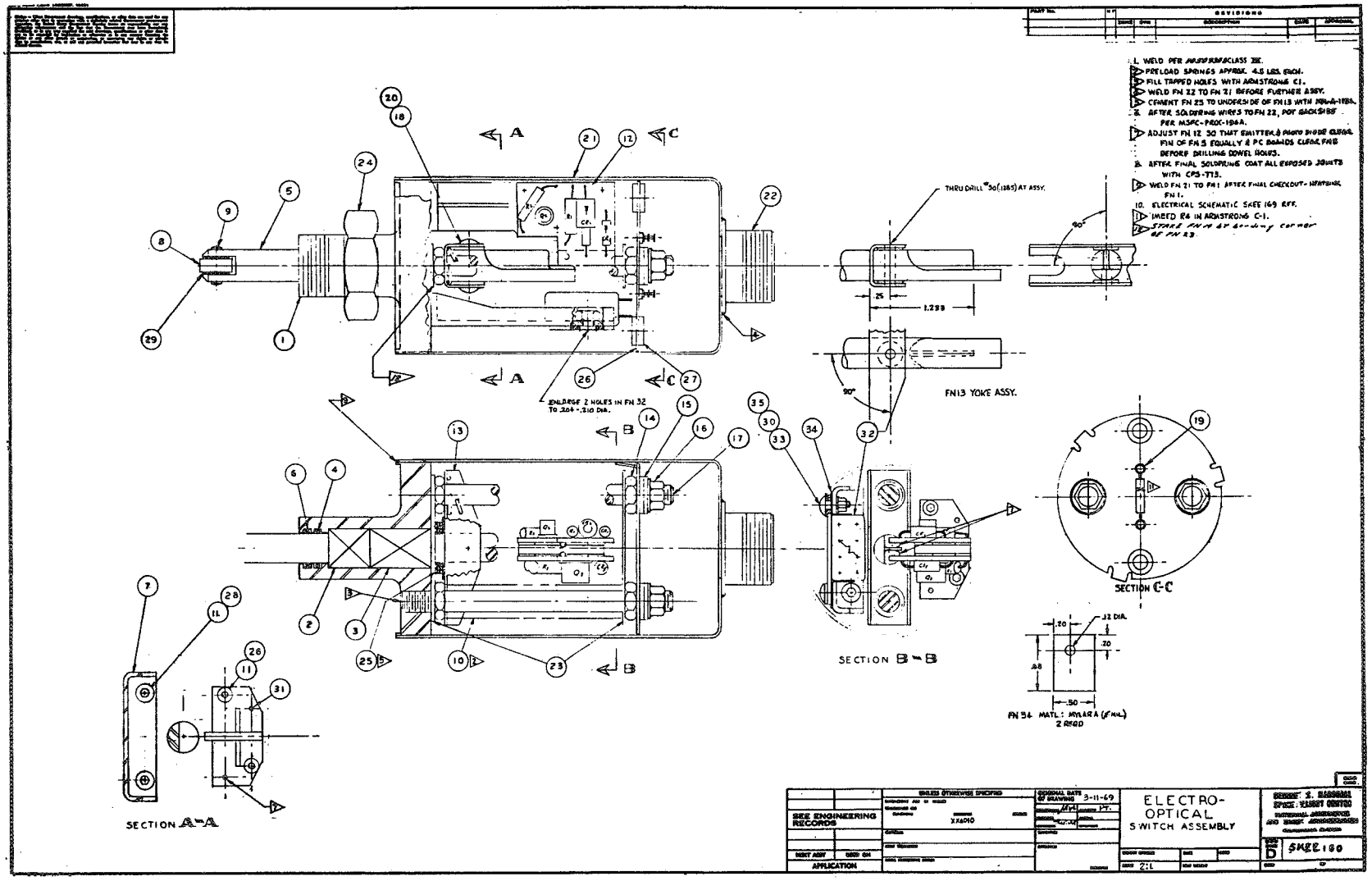


Figure B-2. Electro-Optical Switch, SKEE 160 (Sheet 1 of 6)

DESIGN AND OPERATING REQUIREMENTS

1. Termination: hermetically sealed SST Shell to mate with MS3106R-14S-6S
2. Sealing: Relay is hermetically sealed; actuator assembly is sealed per KSC-STD-131 Para. 5.3.2
3. Mounting: Plate through-hole with keying
4. Contact Arrangement: SPDT
5. Material of Case and Connector: Weldable corrosion resistant steel
6. Input Power: 18 to 30 VDC
7. Actuator Approach (angular range): 0 to 30 degrees
8. Contact Rating: 1.5 amperes inductive and 3 amperes resistive at 28 V DC and at 115 V AC
9. Pretravel: 0.20 to 0.30 inches
10. Differential Travel : 0.010 inches maximum
11. Overtravel: 0.45 to 0.55 inches
12. Axial Operating Forces: 6 lbs. weight minimum of beginning of travel
    25 lbs. weight maximum at total travel
13. Response Time: 30 milliseconds maximum
14. Repeatability: 0.005 inches maximum deviation
15. Low Temperature: 5°F for 2 hours (KSC-STD-164)
16. High Temperature: 160°F for 72 hours
17. Vibration (Non-operational): Sinusoidal: -10 to 44 Hz at 0.25 in. DA
    44 to 2000 Hz at 25 g peak
    Random: -0.225 G2/Hz (KSC-STD-164)
18. Humidity: 72°F to 160°F at 95 percent humidity
19. Sand and Dust: 4 hours at 77°F
    2 hours at 160°F
    100 to 500 cu ft/min (KSC-STD-164)
20. Salt Fog: 5 percent for 240 hours at 95°F (KSC-STD-164)
21. Explosion: 32 plus or minus 5 percent by volume of hydrogen
    Pressure: 13.1 to 15.1 psi (KSC-STD-164)
22. Life: 10000 actuations (KSC-STD-131).

Figure B-2. Electro-Optical Switch, SKEE 160 (Sheet 2 of 6)

PARTS LIST

SIZE ASSY DWG: D | PL SKEE 160

1 FINDING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Base		D	SKEE 147-1		1		
2	Bearing - Sleeve				06DU08	1		Garlock Bearing Prod.
3	Bearing - Sleeve				06DU12	1		Garlock Bearing Prod.
4	"O" Ring			MC266 - 12FA		1		
5	Plunger		B	SKEE-143		1		
6	Wiper		B	SKEE 152		1		
7	Bracket - Relay		B	SKEE 142		1		
8	Bearing - Ball				77-R-2	1		New (or Equiv.) Departure
9	Roll Pin				79-028-125-0375	1		ESNA Corp.
10	Spring - Compression				22	2		California Spring Co.
11	Screw			MS 16995-9		4		
12	Electronic Assembly		B	SKEE-167		1	*	

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
			FN 27 QTY WAS 2		

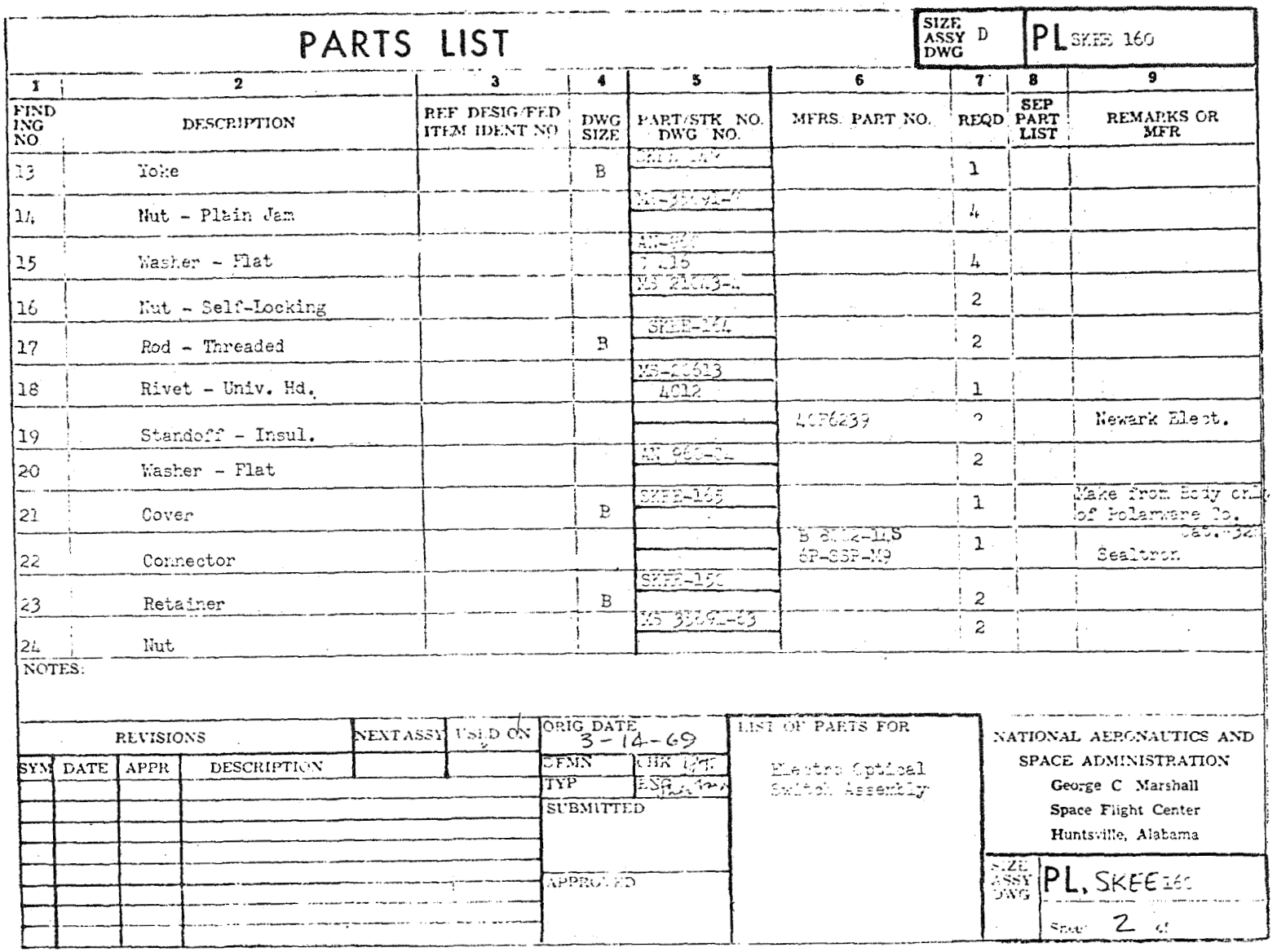
ORIG DATE 3-14-69
DFMN | CHK [illegible]
TYP | ENG [illegible]
SUBMITTED
APPROVED

LIST OF PARTS FOR
Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL, SKEE 160
Sheet 1 of 3

Figure B-2. Electro-Optical Switch, SKEE 160 (Sheet 3 of 6)



PARTS LIST

SIZE ASSY DWG D — PL SKEE 160

1 FIND ING NO	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO	4 DWG SIZE	5 PART/STK NO. DWG NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
13	Yoke		B	SKEE-144		1		
14	Nut - Plain Jam			MS-35692-4		4		
15	Washer - Flat			AN-960 7 435		4		
16	Nut - Self-Locking			MS 21043-4		2		
17	Rod - Threaded		B	SKEE-141		2		
18	Rivet - Univ. Hd.			MS-20613 4C12		1		
19	Standoff - Insul.				4CP6239	2		Newark Elect.
20	Washer - Flat			AN 960-4		2		
21	Cover		B	SKEE-165		1		Make from Body of Polamware Co.
22	Connector				B 3112-14S 6P-6SP-M9	1		Sealectro
23	Retainer		B	SKEE-156		2		
24	Nut			MS 35692-83		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		

ORIG DATE 3-14-69
DFMN — CHK
TYP — ESA
SUBMITTED
APPROVED

LIST OF PARTS FOR
Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG PL, SKEE 160
Sheet 2 of

Figure B-2. Electro-Optical Switch, SKEE 160 (Sheet 4 of 6)

PARTS LIST

SIZE ASSY D DWG | PL SKEE 160

1 FIND ING NO	2 DESCRIPTION	3 REF DESIG FED ITEM IDENT NO	4 DWG SIZE	5 PART STK NO. DWG NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
25	Bumper		B	[illegible]		1		
26	Plate - Stop		B	SKEE 151		1		
27	Grommet - Split			SKE 75E134		3		
28	Washer - Lock			MS 35338-135		4		
29	Washer - Flat			AN-960 C4L		2		
30	Fiber Washer - Shoulder				30F357	2		Newark Elect.
31	Dowel Pin			MS 16 555-602		2		
32	Relay				JP26D1J6A	1		Deutsch/Filtors
33	Screw			MS51957-14		2		
34	Insulation			SKEE 16[illegible]	Mylar (.010 thick)	2		Dupont
35	Nut			MS-21043-04		2		
36	Wire - Hookup Nylon Insul.					As Req'd.		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		

ORIG DATE 3-14-69

DFMN | CHK [illegible]

TYP | ENGR [illegible]

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG | PL. SKEE 160

Sheet 3 of 3

Figure B-2. Electro-Optical Switch, SKEE 160 (Sheet 5 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 167

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Bracket		B	[illegible]		1		
2	Circuit Card Assy.		B	SKEE-168		1		
3	Washer-Fiber				30F355	12		Newark Electronics
4	Screw			MS 16995-10		3		
5	Nut-Selflock			MS 21043-3L		3		
6	Insulation			SKEE-167	Mylar A	2		.005 Thick
7	Coat - Conformal				CFS-773	As Req'd		Coast Pro-Seal or Equiv: *
Ref.	Drill Pattern		B	SKEE-170				

NOTES: * Same as KSC-SPEC-Q-0001 Applied per KSC-SPEC-E-0001

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION	SKEE 160	

ORIG DATE 3-14-69

SFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

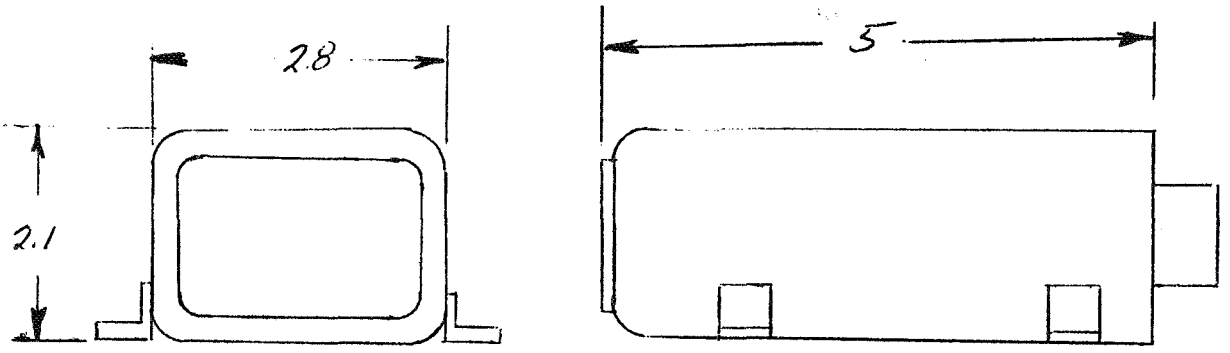
ELECTRONIC ASSEMBLY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL, SKEE-167

Sheet 1 of 1

Figure B-2. Electro-Optical Switch, SKEE 160 (Sheet 6 of 6)



Dimensions (in inches) are maximum allowable.

Manufacturer: Electro-Sonic Control
Manteca, California

Part Number: ESC 1469

Design and Operating Requirements:

1. Termination: To mate with MS3106R-14S-6S
2. Sealing: In accordance with KSC-STD-131, para. 5.3.2
3. Mounting: Surface Mount
4. Contact Arrangement: SPDT
5. Material of Case and Connector: Weldable corrosion resistant steel
6. Input Power: 18 to 36 VDC
7. Actuator Approach (Angular Range): 0 to 90 degrees
8. Contact Rating: 1.5 amperes inductive at 28 VDC; 3 amperes resistive at 115 VAC
9. Sensing Distance Capability: With minimum thickness of 0.10 inch 0.75 inches minimum to 1.25 inches maximum using a ferrous metal target 4 square inches. (Non-ferrous target permissible)
10. Differential Travel: 0.015 inches, maximum
11. Response Time: 30 milliseconds, maximum
12. Repeatability: 0.007 inches, maximum deviation
13. Low Temperature: 5°F for 2 hours (KSC-STD-164)
14. High Temperature: 160°F for 72 hours
15. Vibration (Non-operational): Sinusoidal: -10 to 44 Hz at 0.25 in. DA
    44 to 2000 Hz at 25 g peak
    Random: -0.225 G2/Hz (KSC-STD-164)
16. Humidity: 72°F to 160°F at 95 percent humidity

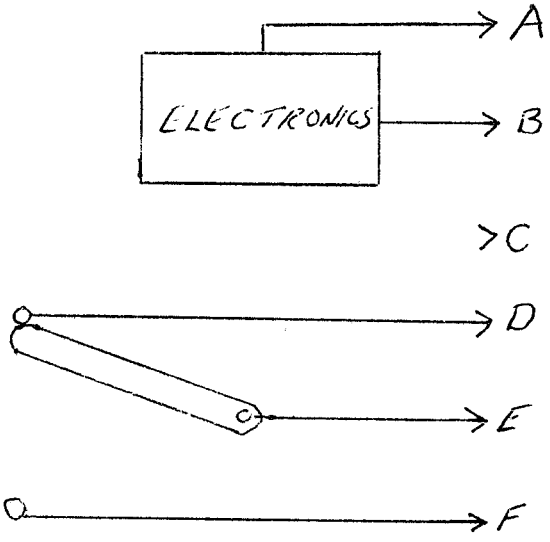
Figure B-3. Proximity Switch, SKEE 161 (Sheet 1 of 2)

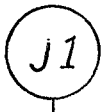
17. Sand and Dust: 4 hours at 77°F
2 hours at 160°F
100 to 500 cu ft/min (KSC-STD-164)

18. Salt Fog: 5 percent for 240 hours at 95°F (KSC-STD-164)

19. Explosion: 32 plus or minus 5 percent by volume of hydrogen
Pressure: 13.1 to 15.1 psi (KSC-STD-164)

20. Life: 10000 actuations (KSC-STD-131).





PIN	FUNCTION
A	+28 VOLTS
B	-28 VOLTS
C	NOT USED
D	NORMALLY CLOSED CONTACT
E	COMMON
F	NORMALLY OPEN CONTACT

Figure B-3. Proximity Switch, SKEE 161 (Sheet 2 of 2)

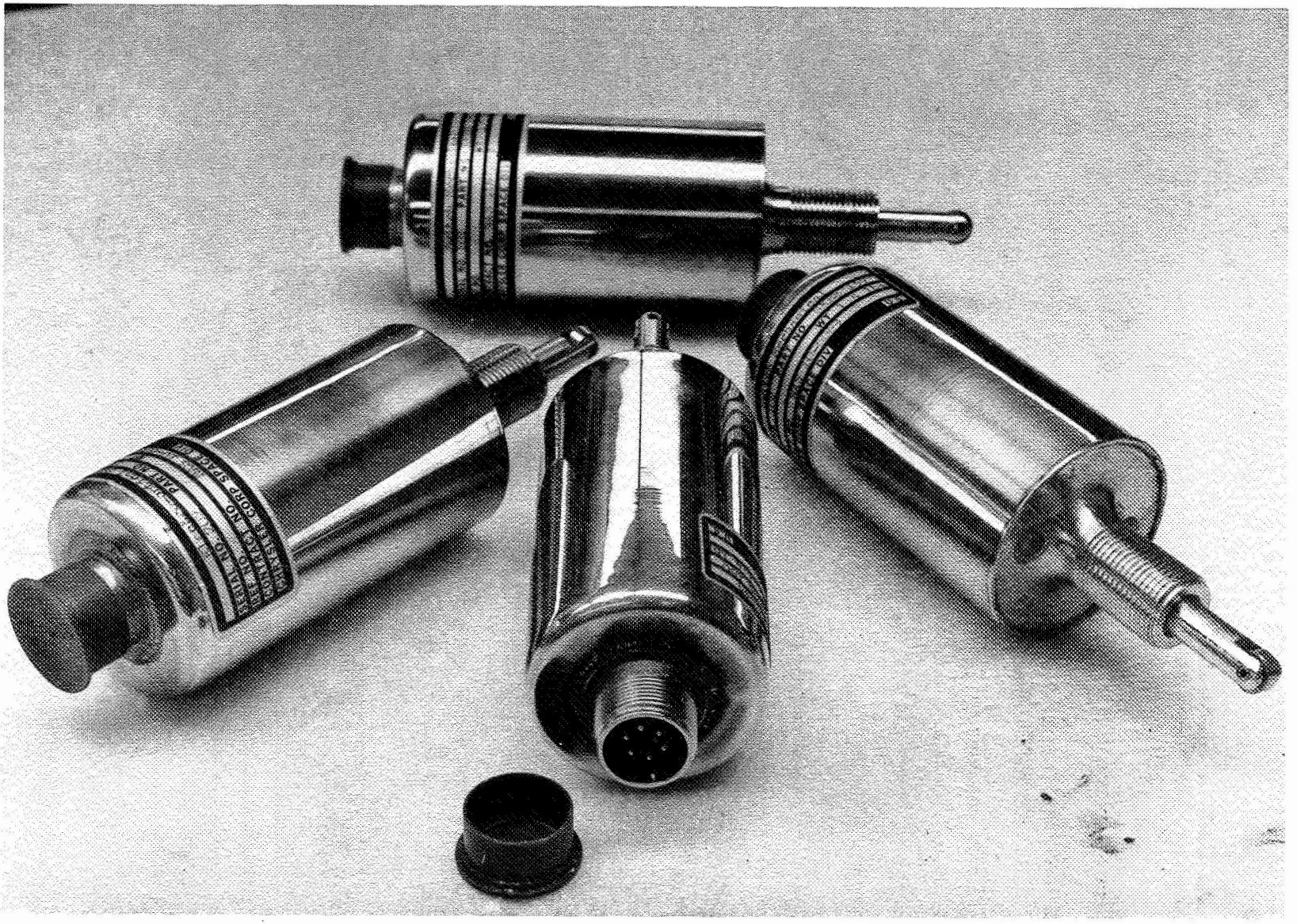


Figure B-4. Mechanical and Electro-Optical Switches

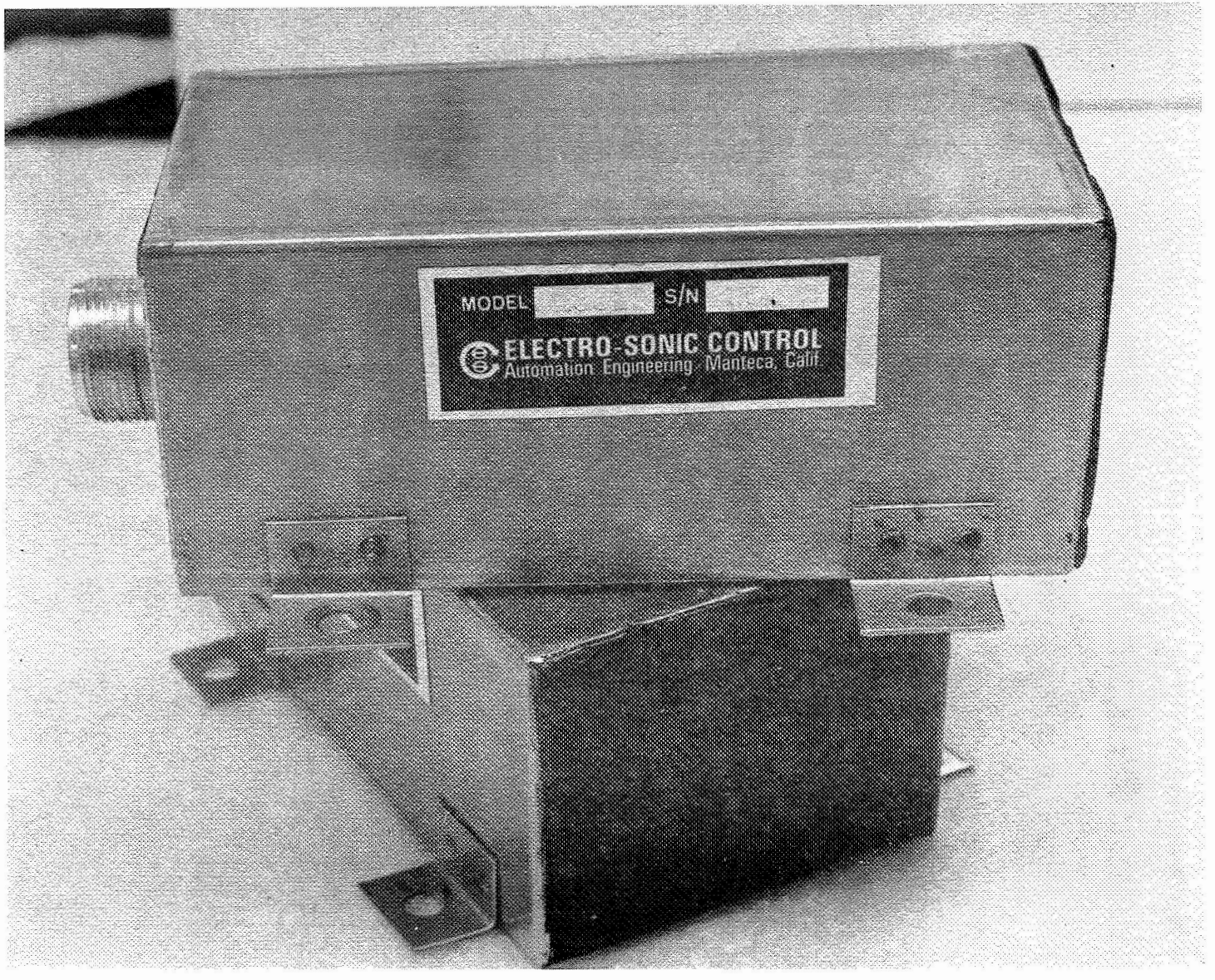


Figure B-5. Proximity Switches

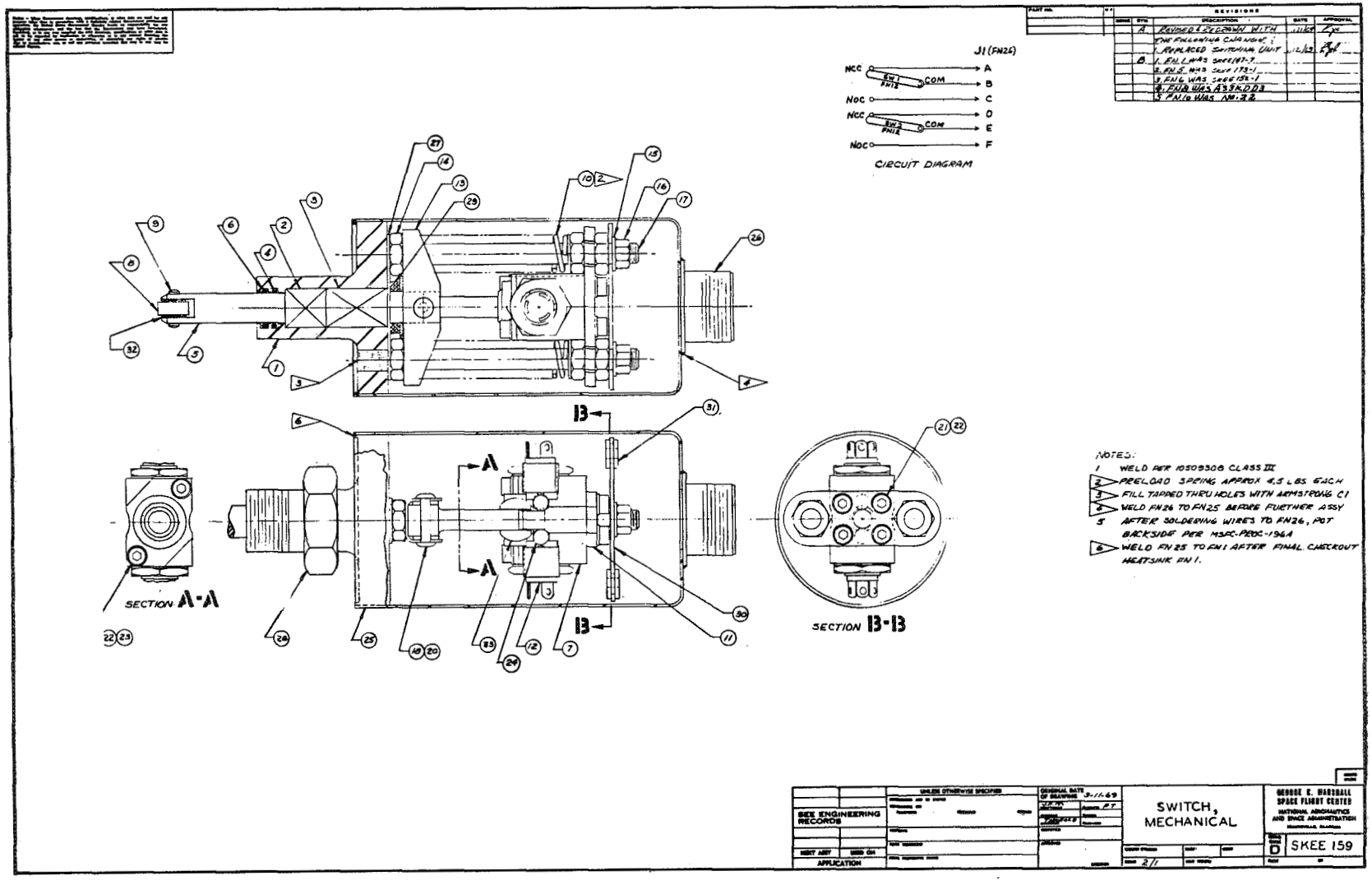


Figure B-6. Redesigned Mechanical Switch, SKEE 159B (Sheet 1 of 4)

PARTS LIST

SIZE ASSY DWG: PL SKEE159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Base		D	SKEE147-7		1		
2	Bearing - SLEEVE				06DU08	1		Garlock Bearing Prod.
3	Bearing - SLEEVE				06DU12	1		Garlock Bearing Prod.
4	"O" Ring			AN123863-110		1		Parker Size No. 2-110
5	Plunger		B	SKEE 173-1		1		
6	Wiper		B	SKEE152-1		1		
7	Block-Switch Mounting		B	SKEE175				
8	Bearing - Ball				A33KDD3			Fafnir
9	Roll Pin				79-028-125-0375	1		ESNA Corp.
10	Spring-Compression				22	2		California Spring Co.
11	Plate-Switch Support			SKEE-172		1		
12	Switch				10AT17-01	2		Texas Instruments Klixon Div.

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE 11-26-69

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Switch
Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 159

Sheet 1 of 3

Figure B-6. Redesigned Mechanical Switch, SKEE 159B (Sheet 2 of 4)

PARTS LIST

SIZE ASSY DWG: PL SKEE-159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
13	Yoke		B	SKEE 149		1		
14	Nut - Plain Jam			MS-35691-7		6		
15	Washer - Flat			AN960 C416		4		
16	Nut - Self-Locking			MS-21043-4		2		
17	Rod - Threaded		B	SKEE 164		2		
18	Rivet			MS-20613 4C12		1		
20	Washer - Flat			AN-960-C4		2		
21	Screw			MS-16995-17		4		
22	Lockwasher			MS-35338-136		6		
23	Screw			MS-16995-16		2		
24	Ball				AK5	2		REC 3/16 DIA. Stainless

NOTES:

REVISIONS SYM	DATE	APPR	DESCRIPTION	NEXT ASSY	USED ON
B					

ORIG. DATE

DFMN CHK

TYP ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Switch Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 159

Sheet 2 of 3

Figure B-6. Redesigned Mechanical Switch, SKEE 159B (Sheet 3 of 4)

PARTS LIST

SIZE ASSY DWG: PL SKEE 159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO	4 DWG SIZE	5 PART/STK NO. DWG NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
25	Cover		B	SKEE 165		1		Make from Polar Ware Co. Body only of Cat. #32K
26	Connector				B8002-14S 6P-SSP-M9	1		Sealtron
27	Retainer		B	SKEE 150		1		
28	Nut			MS35691-63		2		
29	Bumper		B	SKEE [illegible]		1		
30	Plate - Stop		B	SKEE 174		1		
31	Grommet; Split			SDS 703N3A		2		
32	Washer - Flat			AN 960 C4L		2		
33	Bearing			SKEE 176		1		Make from Wafe Products Bearing
34	Wire-Hookup - Mil-W-81044 Awg 28					As Req'd		
35	Wire-Hookup Mil-W-81044-Awg 22					As Req'd		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
B					

ORIG DATE

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Switch Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 159

Sheet 3 of 3

Figure B-6. Redesigned Mechanical Switch, SKEE 159B (Sheet 4 of 4)

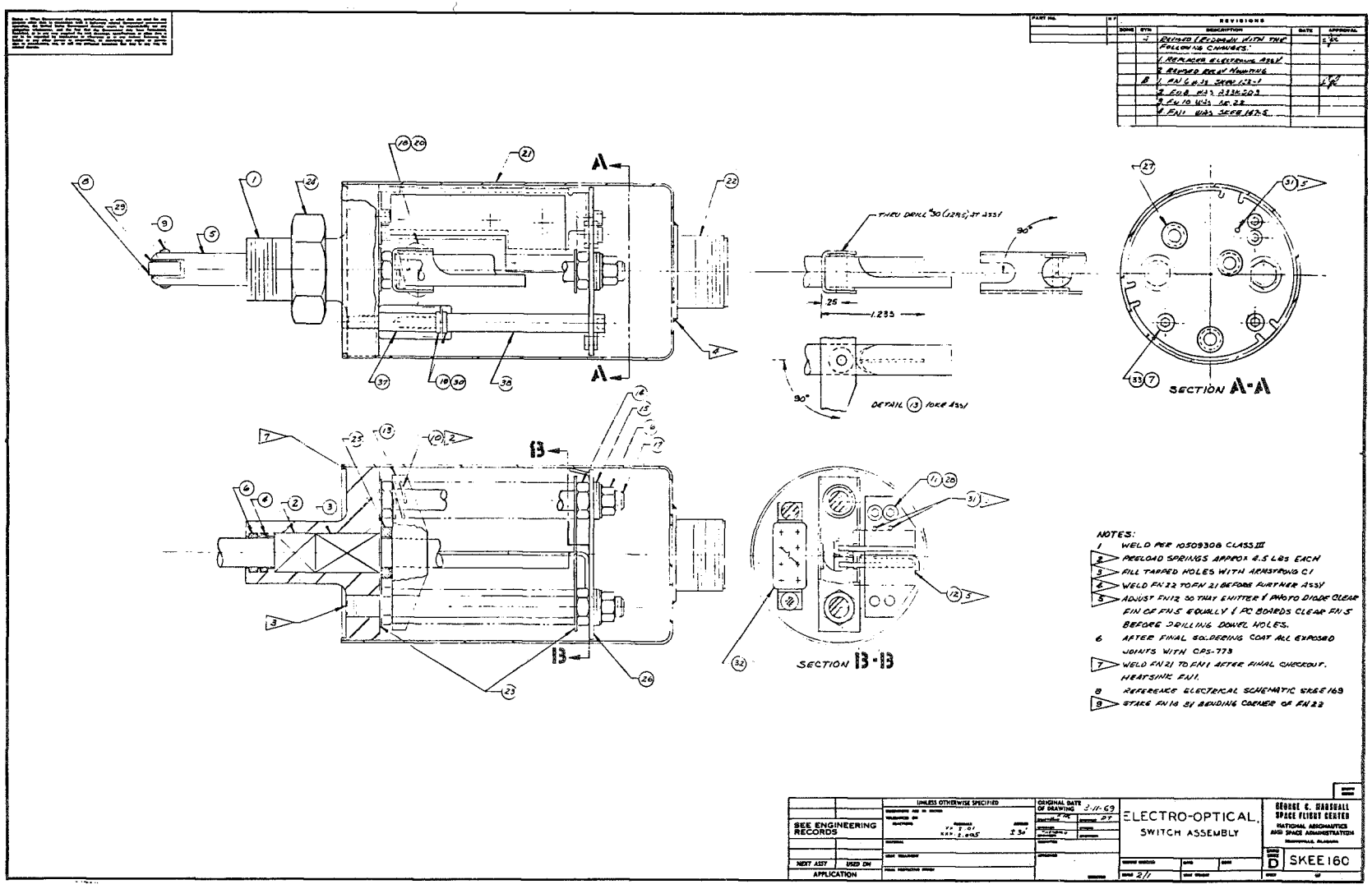


Figure B-7. Redesigned Electro-Optical Switch, SKEE 160B (Sheet 1 of 6)

PARTS LIST

SIZE ASSY DWG D | PL SKEE 160

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Base		D	SKEE 147-9		1		
2	Bearing - Sleeve				06DU08	1		Garlock Bearing Prod.
3	Bearing - Sleeve				06DU12	1		Garlock Bearing Prod.
4	"O" Ring			AN 123863-110		1		Parker Size No. 2-110
5	Plunger		B	SKEE 143-3		1		
6	Wiper		B	SKEE-152-3		1		
7	Lockwasher		B	MS35338-136		2		
8	Bearing - Ball				A33KDD4	1		Fafnir
9	Roll Pin				79-028-125-0375	1		ESNA Corp.
10	Spring - Compression				Stainless LC-038E-18	2		Lee
11	Screw			MS 16995-9		2		#4-40, 1/4 long
12	Electronic Assembly		B	SKEE 184		1	*	

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
B					

ORIG DATE 11-26-69

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG | PL SKEE 160

Sheet 1 of 4

Figure B-7. Redesigned Electro-Optical Switch, SKEE 160B (Sheet 2 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
13	Yoke		B	SKEE 149		1		
14	Nut - Plain Jam			MS-35691-7		4		
15	Washer - Flat			AN-960 C 416		4		
16	Nut - Self-Locking			MS 21043-4		2		
17	Rod - Threaded		B	SKEE 164		2		
18	Rivet - Univ. Hd.			MS 20613 4C12		1		
19	Insulator				972301	2		Gries Reproducer Co.
20	Washer - Flat			AN 960-C4		2		
21	Cover		B	SKEE 165		1		Make from Body of Polarware Co. Cat.#32
22	Connector				B 8002-14S 6P-SSP-M9	1		Sealtron
23	Retainer		B	SKEE 150		2		
24	Nut			MS 35691-63		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR
Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 160

Sheet 2 of 4

Figure B-7. Redesigned Electro-Optical Switch, SKEE 160B (Sheet 3 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
25	Bumper		B	SKEE 183		1		
26	Plate - Stop		B	SKEE 179		1		
27	Grommet - Split			SKS 708N3A		3		
28	Washer - Lock			MS 35338-135		2		
29	Washer - Flat			AN 960 C4L		2		
30	Insulator - Screw				974304	2		Gries Reproducer Co.
31	Dowel Pin			MS 16 555-601		2		
32	Relay				3SBK-103SA2	1		G.E. Electric
33	Screw			MS 16995-17		2		
34	Insulation				Mylar A (.010 thick)	As Req'd.		Dupont
35	Nut - Self locking			MS-21043-04		2		
36	Wire - Hookup Mil-W-81044					As Req'd.		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
B					

ORIG DATE

DFMN CHK

TYP ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

George C. Marshall Space Flight Center

Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 160

Sheet 3 of 4

Figure B-7. Redesigned Electro-Optical Switch, SKEE 160B (Sheet 4 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
37	Spacer			SKEE 178-1		2		
38	Spacer			SKEE 178-3		2		
39	Screw			MS16995-10		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL, SKEE 160

Sheet 4 of 4

Figure B-7. Redesigned Electro-Optical Switch, SKEE 160B (Sheet 5 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 184

1 FINDING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Bracket		B	SKEE 177		1		
2	Circuit Card Assy.		B	SKEE		1	*	
3	Washer Fiber				30F355	12		Newark Electronics
4	Screw			MS 16995-4		3		
5	Nut-Selflock			MS 21043-02		3		
7	Potting Compound				CPS-773	As Req'd		Coast Pro-Seal or Equiv. *

NOTES:

* Same as KSC-SPEC-Q-0001 Applied per KSC-SPEC-E-0001

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION	SKEE 160A SKEE 160B	

ORIG DATE 11-26-69

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electronic Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 184

Sheet 1 of 1

Figure B-7. Redesigned Electro-Optical Switch, SKEE 160B (Sheet 6 of 6)

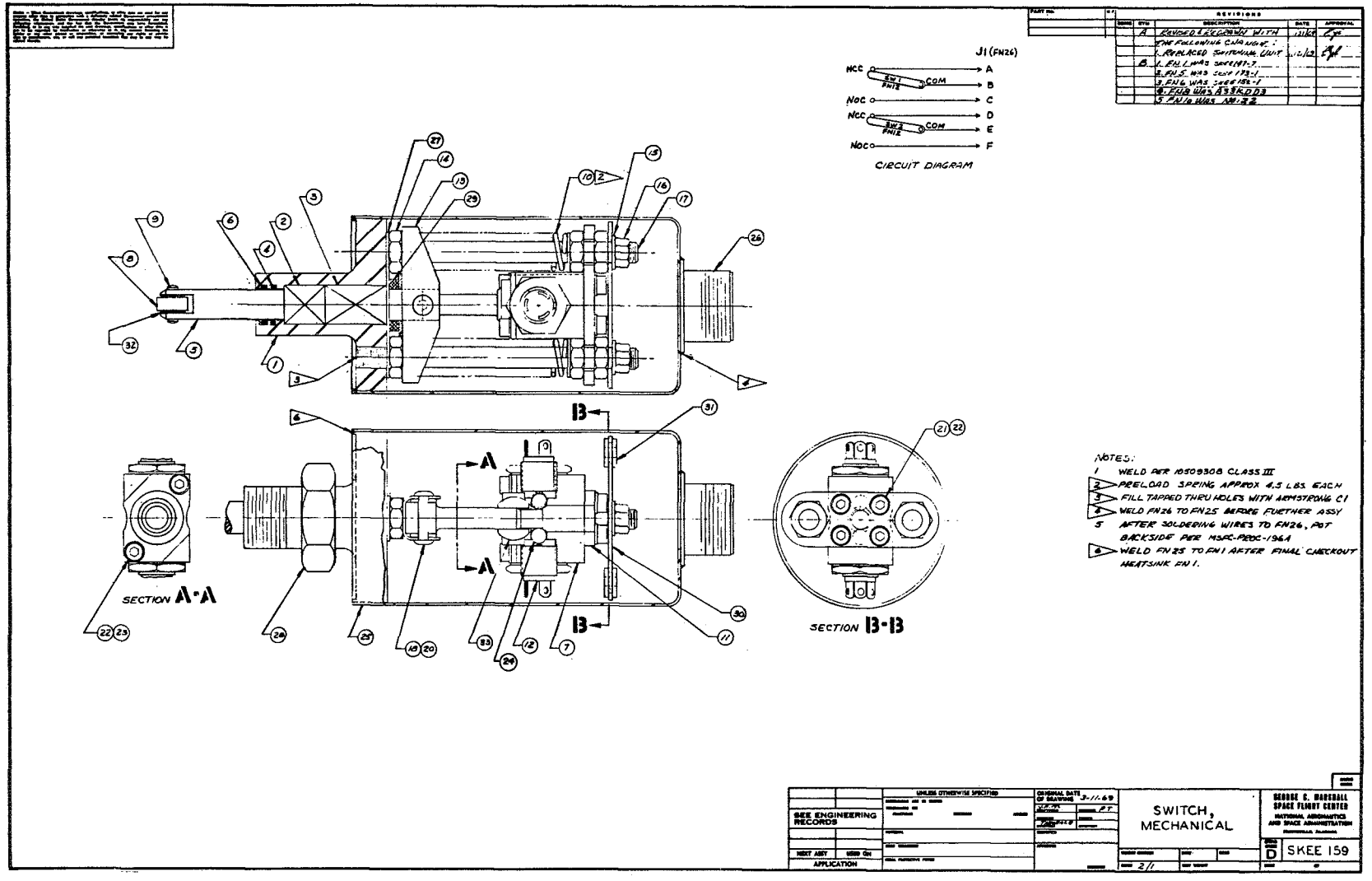


Figure B-8. Refurbished Mechanical Switch, SKEE 159A (Sheet 1 of 4)

PARTS LIST

SIZE ASSY DWG: PL SKEE159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Base		D	SKEE147-11		1		
2	Bearing - SLEEVE				06DU08	1		Garlock Bearing Prod.
3	Bearing - SLEEVE				06DU12	1		Garlock Bearing Prod.
4	"O" Ring			AN123863-110		1		Parker Size No. 2-110
5	Plunger		B	SKEE -173-3		1		
6	Wiper		B	SKEE152-3		1		
7	Block-Switch Mounting		B	SKEE175		1		
8	Bearing - Ball				A33KDD4	1		Fafnir
9	Roll Pin				79-028-125-0375	1		ESNA Corp.
10	Spring-Compression				LC-038E-18 Stainless	2		LEE
11	Plate-Switch Support			SKEE-172				
12	Switch				10AT17-01	2		Texas Instruments Klixon Div.

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
B					

ORIG DATE 11-26-68
DFMN | CHK
TYP | ESGK
SUBMITTED
APPROVED

LIST OF PARTS FOR
Switch
Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL, SKEE 159
Sheet 1 of 3

Figure B-8. Refurbished Mechanical Switch, SKEE 159A (Sheet 2 of 4)

PARTS LIST

SIZE ASSY DWG: PL SKEE-159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
13	Yoke		B	SKEE 149		1		
14	Nut - Plain Jam			MS-35691-7		6		
15	Washer - Flat			AN960 C416		4		
16	Nut - Self-Locking			MS-21043-4		2		
17	Rod - Threaded		B	SKEE 164		2		
18	Rivet			MS-20613 4C12		1		
20	Washer - Flat			AN-960-C4		2		
21	Screw			MS-16995-17		4		
22	Lockwasher			MS-35338-136		6		
23	Screw			MS-16995-16		2		
24	Ball				AK5	2		PIC 3/16 Dia. Stainless

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Switch Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY WG: PL SKEE 159

Sheet 2 of 3

Figure B-8. Refurbished Mechanical Switch, SKEE 159A (Sheet 3 of 4)

PARTS LIST

SIZE ASSY DWG: PL SKEE 159

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
25	Cover		B	SKEE 165		1		Make from Polar Ware Co. Body only of CAT. #32K
26	Connector				B8002-14S 6P-SSP-M9	1		Sealtron
27	Retainer		B	SKEE 150				
28	Nut			MS35691-63		2		
29	Bumper		B	SKEE 185		1		
30	Plate - Stop		B	SKEE 174		1		
31	Grommet; Split			SDS 708N3A		2		
32	Washer - Flat			AN 960 C4L		2		
33	Bearing			SKEE-176		1		Make from Wafe Products Bearing
34	Wire-Hookup Mil-W-81044 Awg 28					As Req'd		
35	Wire-Hookup Mil-W-81044 Insul.Awg 22					As Req'd		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE

DFMN | CHK

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Switch Mechanical

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 159

Sheet 3 of 3

Figure B-8. Refurbished Mechanical Switch, SKEE 159A (Sheet 4 of 4)

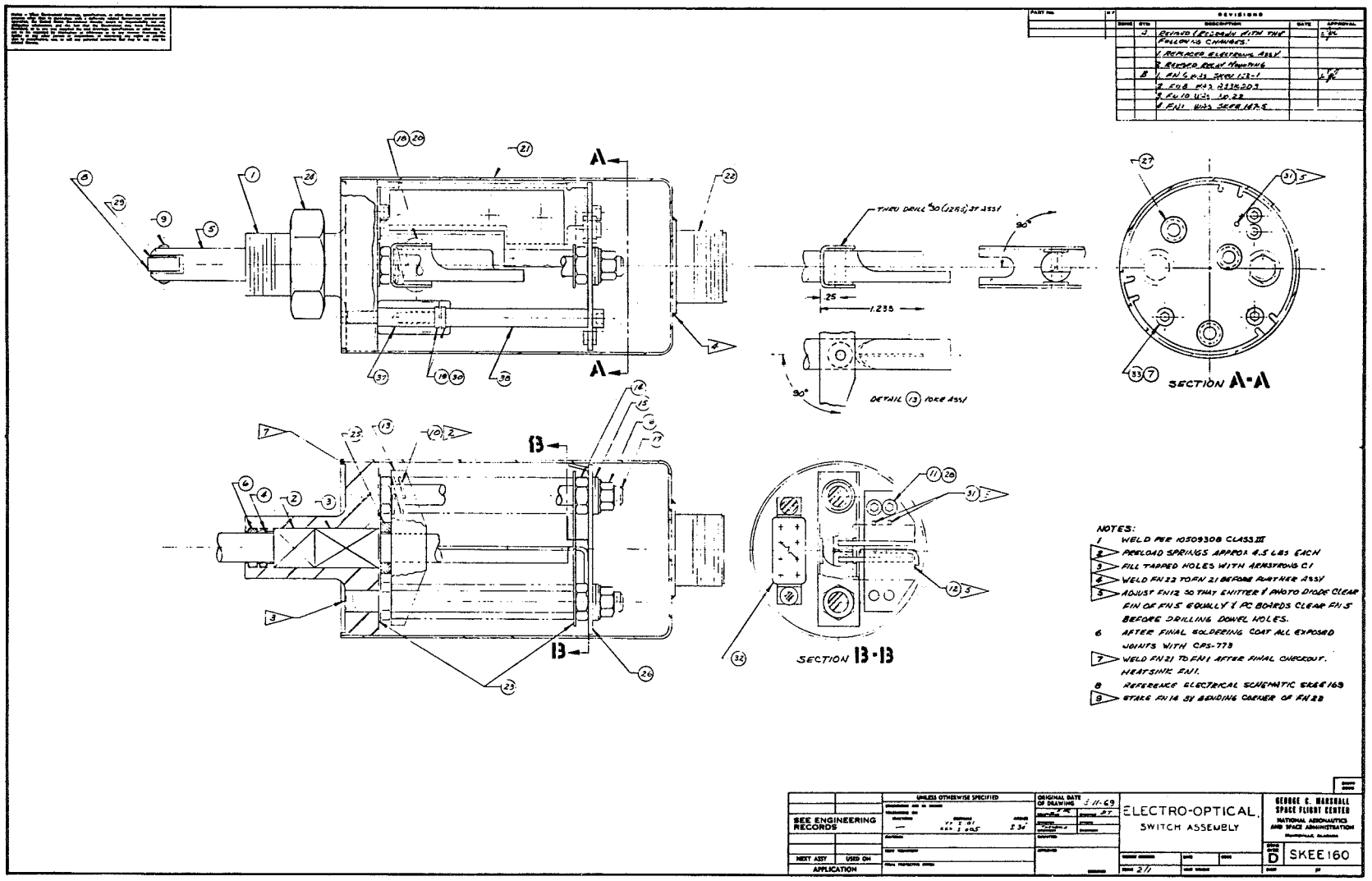


Figure B-9. Refurbished Electro-Optical Switch, SKEE 160A (Sheet 1 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FINDING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Base		D	SKEE 147-5		1		
2	Bearing - Sleeve				O6DU08	1		Garlock Bearing Prod.
3	Bearing - Sleeve				O6DU12	1		Garlock Bearing Prod.
4	"O" Ring			AN123863-110		1		Parker Size No. 2-110
5	Plunger		B	SKEE 143-1		1		
6	Wiper		B	SKEE 152-1		1		
7	Lockwasher		B	MS 35338-136		2		
8	Bearing - Ball				A33KDD3	1		Fafnir
9	Roll Pin				79-028-125-0375	1		ESNA Corp.
10	Spring - Compression				22	2		California Spring Co.
11	Screw			MS 16995-9		2		
12	Electronic Assembly		B	SKEE 184		1	*	

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE 11-26-69
DFMN CHK
TYP ENGR
SUBMITTED
APPROVED

LIST OF PARTS FOR
Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL, SKEE 160
Sheet 1 of 4

Figure B-9. Refurbished Electro-Optical Switch, SKEE 160A (Sheet 2 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
13	Yoke		B	SKEE 149		1		
14	Nut - Plain Jam			MS-35691-7		4		
15	Washer - Flat			AN-960 C 416		4		
16	Nut - Self-Locking			MS 21043-4		2		
17	Rod - Threaded		B	SKEE 164		2		
18	Rivet - Univ. Hd.			MS 20613 4C12		1		
19	Insulator				972301	2		Gries Reproducer
20	Washer - Flat			AN 960C-C4		2		
21	Cover		B	SKEE 165		1		Make from Body only of Polarware
22	Connector				B 8002-14S 6P-SSP-M9	1		Co. Cat.#32K Sealtron
23	Retainer		B	SKEE 150		2		
24	Nut			MS 35691-63		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
B					

ORIG DATE

DFMN CHK

TYP ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL, SKEE 160

Sheet 2 of 4

Figure B-9. Refurbished Electro-Optical Switch, SKEE 160A (Sheet 3 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FINDING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
25	Bumper		B	SKEE 185		1		
26	Plate - Stop		B	SKEE 179		1		
27	Grommet - Split			SDS 708N3A		3		
28	Washer - Lock			MS 35338-135		2		
29	Washer - Flat			AN 960 C4L		2		
30	Insulator - Screw				974304	2		Gries Reproducer Co.
31	Dowel Pin			MS 16 555-60		2		
32	Relay				3SBF1035A2	1		General Elec.
33	Screw			MS 16995-17		2		
34	Insulation				Mylar A (.010 thick)	As Req'd		Dupont
35	Nut-Self Locking			MS21043-04		2		
36	Wire - Hookup Mil-W-81044 Insul.					As Req'd.		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE

DFMN | CHK

TYP | ENG

SUBMITTED

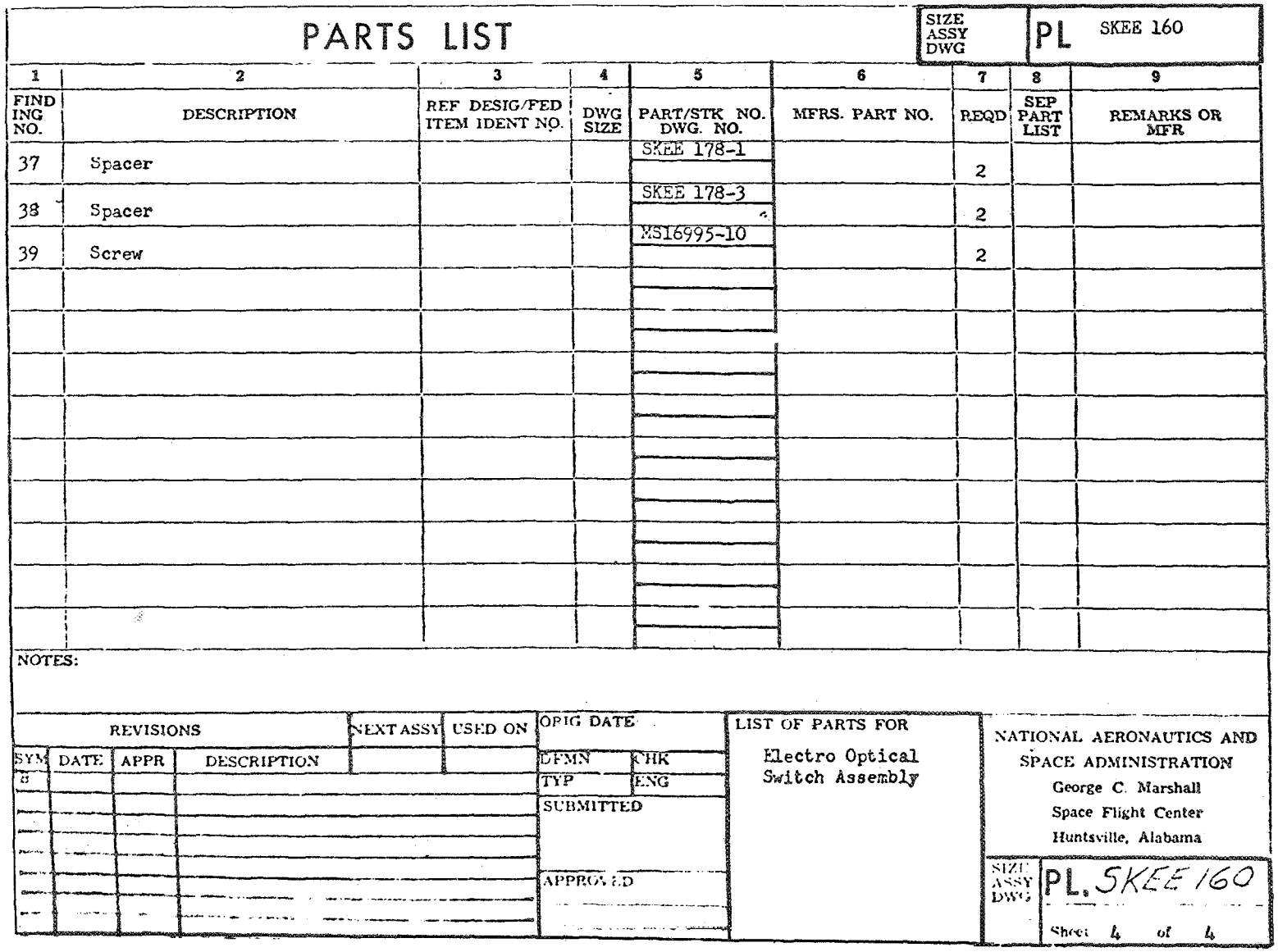
LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C Marshall Space Flight Center
Huntsville, Alabama

PL SKEE 160

Figure B-9. Refurbished Electro-Optical Switch, SKEE 160A (Sheet 4 of 6)



PARTS LIST

SIZE ASSY DWG: PL SKEE 160

1 FINDING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
37	Spacer			SKEE 178-1		2		
38	Spacer			SKEE 178-3		2		
39	Screw			MS16995-10		2		

NOTES:

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
A					

ORIG DATE

DFMN CHK

TYP ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electro Optical Switch Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

George C. Marshall Space Flight Center

Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 160

Sheet 4 of 4

Figure B-9. Refurbished Electro-Optical Switch, SKEE 160A (Sheet 5 of 6)

PARTS LIST

SIZE ASSY DWG: PL SKEE 184

1 FIND ING NO.	2 DESCRIPTION	3 REF DESIG/FED ITEM IDENT NO.	4 DWG SIZE	5 PART/STK NO. DWG. NO.	6 MFRS. PART NO.	7 REQD	8 SEP PART LIST	9 REMARKS OR MFR
1	Bracket		B	SKEE 177		1		
2	Circuit Card Assy.		B	SKEE		1	*	
3	Washer-Filter				307355	12		Newark Electronic
4	Screw			MS 16995-4		3		
5	Nut-Selflock			MS 21043-C2		3		
7	Potting Compound				CPS-773	As Req'd		Coast Pro-Seal or Equiv. *

NOTES:

* Same as KSC-SPEC-Q-0001 Applied per KSC-SPEC-E-0001

REVISIONS				NEXT ASSY	USED ON
SYM	DATE	APPR	DESCRIPTION		
			SKEE 160A		

ORIG DATE 11-26-63

CFMN | DR

TYP | ENG

SUBMITTED

APPROVED

LIST OF PARTS FOR

Electronic Assembly

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama

SIZE ASSY DWG: PL. SKEE 184

Sheet 1 of 1

Figure B-9. Refurbished Electro-Optical Switch, SKEE 160A (Sheet 6 of 6)

COMPONENT LIST		
REF DES	DESCRIPTION	TYPE/PART NO.
CR1	ZENER DIODE 5.6V	1N3827A
CR2	ZENER DIODE 5.6V	1N3827A
CR3	LIGHT EMITTING DIODE	T1L01
CR4	GENERAL PURPOSE DIODE 600V 1A	1N645
CR5	ZENER DIODE 47V 400 mW	1N977
J1	CONNECTOR	SEALTRON B-8002-14S-6P-SSP-~~SB~~ or PHYS. SC. HP04-14S-6P-F2
K1	RELAY	FILTORS JR26G1J6A or GENERAL ELECTRIC 3SBK103SA2
Q1	LIGHT SENSOR	LS 600
Q2	TRANSISTOR	2N2907A
Q3	TRANSISTOR	2N3019
R1	RESISTOR 590 OHM 1W	RW70U5900F
R2	RESISTOR 39.2K 1W	RN60C3922F
R3	RESISTOR 10K 1W	RN60C1002F
R4	RESISTOR 348 OHM 3W	RW79U3480F

REVISIONS			
	DESCRIPTION	DATE	APPROV

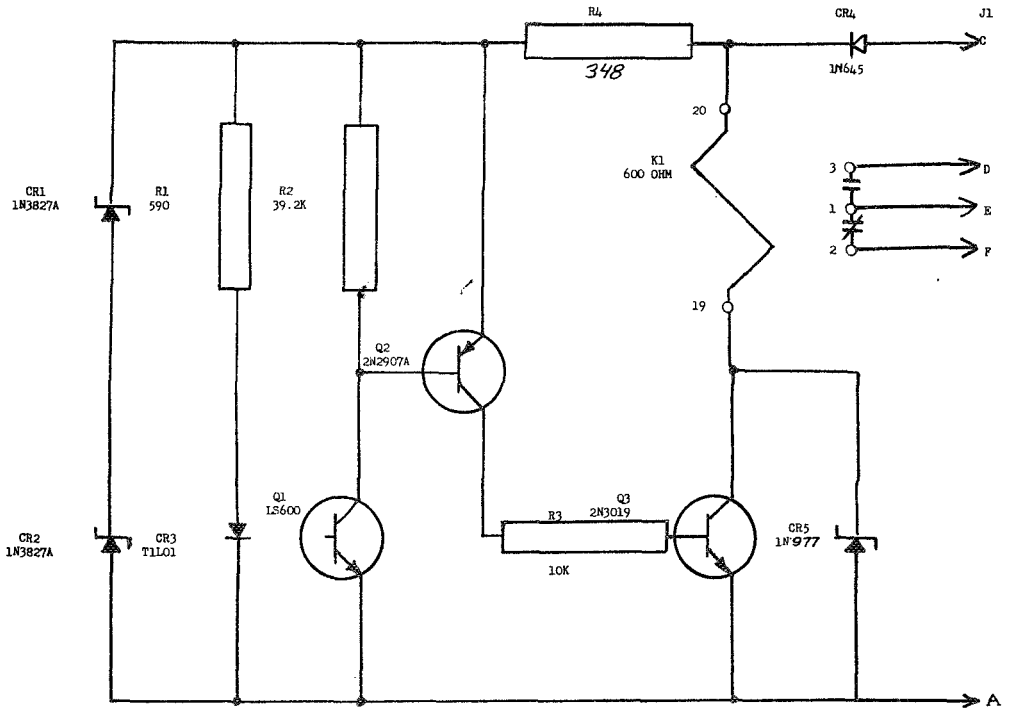


Figure B-10. Electro-Optical Schematic Diagram

NASA-KSC JUL/70